Linguistic and Musical Information-Processing in Children with Autism

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Thesis submitted in partial fulfilment of
the requirements for the degree of Doctor
of Philosophy of the University of London

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October 2004

ABSTRACT

This thesis focuses upon investigating the relationship between linguistic and musical information-processing in children with autism. The framework for the experiments presented herein derives from three main sources: first, studies highlighting enhanced musical pitch processing abilities in individuals with autism; second, findings from neurological and cognitive studies showing that social stimuli have substantially reduced salience for those with the disorder; and third, investigations reporting higher-level language processing deficits in such individuals. Theories of autism that variously account for the featurally-biased information-processing style (weak central coherence hypothesis) (Frith, 1989a; Happé, 1999), atypical perceptual processing (theory of enhanced perceptual processing) (Mottron & Burack, 2001), as well as the social and communicative abnormalities in the disorder, are outlined and discussed within the context of the experimental findings.

The experiments presented in this thesis examined the relationship between perceptual processing of pitch information in speech stimuli, and musical stimuli, and higher-level linguistic abilities, in children with autism. Additionally, a pilot study into rhythmic processing was conducted. The main findings showed that whilst children with autism exhibited enhanced perceptual processing of pitch in speech stimuli, marked deficits in the understanding of the linguistic function of prosodic cues were in evidence. Furthermore, children with autism failed to consistently outperform their controls in experimental conditions comprising non-social stimuli. These findings suggest that the enhanced perceptual processing in autism is a consequence of atypical social development. Evidence suggesting reduced neural specialisation in the speech domain was explained by an atypical modularisation hypothesis. Taken together, the findings suggest that many aspects of speech processing, as well as more general auditory processing, are down-stream effects of an early reduction in the salience of social information in autism. Consequently, these children develop finely-tuned appreciation of the physical features of stimuli, and show difficulties in interpreting socially relevant information meaningfully.

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ACKNOWLEDGEMENTS

I would like to acknowledge the help and kindness of my friends and colleagues at Goldsmiths College. I would particularly like to thank my supervisor Dr Pam Heaton, whose guidance, warm support, and enthusiasm for my work have been invaluable. I could not have wished for a more inspirational and wonderful PhD supervisor.

Aside from my colleagues at Goldsmiths College, several people have given me practical assistance during the course of my PhD. I would particularly like to acknowledge Sue Peppé of Queen Margaret College, Edinburgh, for her kind collaboration regarding the use of her PEPS-C test, and also her husband Gavin King-Smith for technical assistance with this test battery. I am grateful to both Greg Wallace and Rhonda Booth, who kindly provided me with some test stimuli at the beginning of my PhD. I would also like to mention Franck Ramus, who provided me with some helpful comments on my written work.

I am greatly indebted to the wonderful staff of the many different schools who, out of the sheer kindness of their hearts, have welcomed my research to be carried out their premises. I would particularly like to mention Stephanie Lord, Sarah Sherwood, and Sarah Bryant of the Heathermount School; Monica Kitchlew-Wilson and Janice Simpson of the Furzedown Primary School; Sue Stalley of the Alexandra School; Sarah Moffat and Sue Piper of the Prior's Court School; and both Allan Shippey and Sarah Courtney of the Churchfield School. Thanks must also be given to all the delightful children, who kindly participated in my studies; for their kind assistance, enthusiasm, and thoroughly good work.

Mary Cochrane has been the loveliest, brightest, and most caring friend, and a great source of inspiration and support during the course of my PhD studies. I would like to wish her all the very best of luck with completing her own PhD thesis.

My heartfelt thanks go to my mother and father, for their love and support, and without whom half of the kind of life I have led would not have been possible. I would also like to acknowledge the kind support of my brothers Esa, and Antti and Mikko and their families. Dick and Pauline Pasley have been a wonderful source of warm support throughout, and have provided many relaxing breaks at their home.

Finally, I would like to express my deepest gratitude to my fiancé John, for his love, care, and patience, which are without bounds. I would also like to mention the helpful discussions and comments on my work, for coming up with the experimental paradigm employed in experiment three, as well as his endless assistance with English grammar, and anything to do with computers and technology. He has miraculously navigated along through the lightest and the darkest of days.

DEDICATION

This thesis is dedicated to the memory of my grandparents, Veli (1916-1999) and Helmi (1923-2003) Putaala.

In China, children with autism are called "stars" for they are both captivating and utterly unreachable.

Mingsheng Wei, personal communication

"Then I stayed still and I looked at my watch and I stayed still for 27 minutes. And then I heard Father start the engine of his van. I knew it was his van because I heard it very often and it was nearby and I knew it wasn't any of the neighbours' cars because the people who take drugs have a Volkswagen camper van and Mr Thompson who lives at number 40 has a Vauxhall Cavalier and the people who live at number 34 have a Peugeot and they all sound different."

Mark Haddon (2003), an excerpt from his novel "The Curious Incident of the Dog in the Night-Time" (p.159)

Chapter One

General Introduction

Autism is a pervasive neurodevelopmental disorder affecting brain function. Aetiological studies have shown that heritability estimates for autism are over 90 per cent, and are thereby greater than for any other psychiatric disorder (Bailey, Le Couteur, Gottesman, Bolton, Simonoff, Yuzda, & Rutter, 1995). It is presently estimated that anywhere between two and seven interacting genes are involved in the development of this disorder (Pickles, Bolton, Macdonald, Bailey, Le Couteur, Sim, & Rutter, 1995; Santangelo & Folstein, 1999). To complicate matters, no strict link has been made between a gene and a phenotype; this is to say that autism is a non-deterministic syndrome where an abnormal gene can express itself differently in different individuals (Dawson, Webb, Schellenberg, Dager, Friedman, Aylward, & Richards, 2002). As there is no biological confirmatory test, autism is a behaviourally defined, and therefore dimensional, disorder. Due to the high level of heterogeneity in the behavioural manifestation of autism, to improve diagnostic uniformity, the diagnostic subtypes of autism are arranged on a spectrum according to symptom severity in the Diagnostic and Statistical Manual of Mental Disorders, 4th edition (DSM-IV) (American Psychiatric Association, 1994), and in the International Classification of Diseases, 10th edition (ICD-10) (World Health Organization, 1992).

In order to meet the diagnosis of an autistic spectrum disorder, individuals must present deficits in the following three domains of functioning, before the age of three years

(APA, 1994; WHO, 1992). First, reciprocal social interaction, including a failure to appropriately use facial and non-verbal gestures to regulate social interaction; an inability to develop peer relationships; a lack of empathy; and an inability to infer other people's mental states on the basis of their experiences. Second, communication, including a lack or delay in language development without an attempt to compensate with gestures; an inability to initiate and maintain conversation; stereotyped and repetitive use of language; and a lack of imaginative play. Finally, cognitive rigidity, manifested as stereotyped and repetitive patterns of interests and behaviour; adherence to routines and sameness; repetitive motor movements; and obsessions with parts of objects. Because the level of cognitive functioning is not a defining feature, intellectual abilities of this population range from intellectually impaired (approximately 50% of the population) (Chakrabarti & Fombonne, 2001) to intellectually able.

Recent epidemiological studies of autism have noted a sharp increase in prevalence since 1991 (Fombonne, 2003), and the current estimate is that this disorder affects between 15 and 20 individuals in 10,000 (Chakrabarti & Fombonne, 2001). Whilst the major diagnostic instruments, namely the DSM-IV and the ICD-10, were specifically designed to characterise the core features of autism, other diagnostic instruments have been developed, such as the Autism Diagnostic Interview-Revised (ADI-R) (Le Couteur, Lord, & Rutter, 2003). The availability of an increasing number of diagnostic instruments has made it possible to quantify the diagnostic characteristics of autism more easily, and also to assess the nature of the differences that exist between individuals who meet narrow classifications of the disorder and those who do not (Volkmar, Lord, Bailey, Schultz, & Klin, 2004). This has, in part, resulted in the widening of the diagnostic conceptualisation. Indeed, Volkmar et al. suggest that the growing number of diagnostic measures have allowed researchers to include in their samples individuals, who have narrowly missed the cut-off points for a diagnosis of autism in one test, but reached the criteria in another, without compromising the ability to provide detailed characterisation of the individual's symptoms (see Volkmar et al., 2004). Furthermore, Volkmar and colleagues noted in their recent review of autism that, "it is somewhat ironic that having standardised instruments based on narrow conceptualisations of these three domains of difficulty has also facilitated (the) beginning (of) well-controlled research about individuals who do not meet (the) narrow classifications of autism" (Volkmar et al., 2004, p.136). Consequently, the diagnosis of autism has moved away from what is now believed to be the "classic" type of autism described by Kanner (1943), to a broader phenotype of social, communicative, and behavioural impairments. The broader phenotype is considered to exist when close relatives of an individual with autism exhibit an increased tendency towards cognitive performance and behavioural patterns associated with the disorder, albeit without meeting the diagnostic criteria (see Bailey, Palferman, Heavey, & Le Couteur, 1998, for a review). For example, it is interesting to note that, for Asperger syndrome, there are at least five other widely used diagnostic definitions (Klin & Volkmar, 1997; Leekham, Libby, Wing, Gould, & Gillberg, 2000; Szatmari, Bryson, Boyle, Streiner, & Duku, 2003; Tsai, 1992; Wing, 1981), in addition to those provided by the DSM-IV and ICD-10. Due to the relative rarity of autism, and the lack of consensus between clinicians about reliable diagnostic criteria for clearly defined phenotypic subgroups, the umbrella term of "autistic spectrum disorder" will be used in this thesis to refer to the children who will participate in the reported experiments.

As was mentioned above, one of the core diagnostic features of autism is language impairment (APA, 1994; WHO, 1992). In the earliest description of autism, Leo Kanner (1943) noted a host of communicative abnormalities in 11 children with autism. Of these 11 children, eight were verbal, but their speech had several unusual characteristics. For example, many showed pronoun reversal, with children referring to themselves as "you"; echolalia, with children imitating or echoing back exact words and phrases often in the exact form in which they had been heard; and the use of "neologisms", with children using words with unique meanings not shared by others. Furthermore, the children were unresponsive to questions, had abnormal prosody, especially with regard to intonation and voice quality, showed difficulties in generalising word meanings, and produced utterances that bore no relationship to the conversational context. Despite observing these abnormalities, Kanner (1943) did not regard language impairment as fundamental to the syndrome he had described. However, in his 1946 follow-up paper he summarised features of language that distinguished children with autism from those with other clinical conditions. It is striking that almost at the same time, Hans Asperger (1944) published a report of four boys with a less severe form of autism, and his description of their language abnormalities shared many common aspects with that of Kanner. For example, Asperger's description made references to prosodic abnormalities (sing-song pattern of speech, odd voice quality, over-exaggerated prosody), unusual choice of words, and "pedantic", stereotyped speech. However, whilst Kanner (1943; 1946) had described children with a profound language disorder showing severe delay and deviancy, the speech of the boys in Asperger's (1944) account was sophisticated-sounding and adult-like. Indeed, Asperger (1979) later proposed that individuals with Asperger syndrome do not show delayed language development, in this way contrasting with children exhibiting "classic" Kanner-type autism. Asperger believed that the language impairment in his group of patients was social, rather than linguistic, in nature. In the past 60 years, research into the language impairment in autism has identified a typical profile, whereby mechanical aspects, such as phonology and syntax, can appear relatively spared, but where severe deficits are universally observed in the higher-level pragmatic, and often semantic, domains (Minshew, Goldstein, & Siegel, 1995; Rapin & Dunn, 2003; Tager-Flusberg, 2001b). Pragmatics have been defined as the social aspects of communication, encompassing the co-ordination of eye contact and speech, and the ability to appreciate the thoughts, interests and opinions of others (Ozonoff & Miller, 1996; Wilkinson, 1998). This area of communication has consistently been identified as being universally and specifically impaired in autism relative to controls and to other aspects of language (Lord & Paul, 1997; Tager-Flusberg, 2000). Thus, individuals with autism experience specific difficulties in communicating flexibly in highly context-dependent social situations. These semantic and pragmatic deficits are highly persistent, in that they are evident even in intellectually unimpaired (full scale intelligence score exceeding 70) individuals in adulthood, when other primary symptoms have subsided (Simmons & Baltaxe, 1975).

Although language abnormalities, other than those seen in pragmatics, are not universal features of autism, studies have reported striking deficits in the area of semantics. For example, individuals with autism have been found to utilise semantic information to help encode and recall verbal material to a significantly lesser extent than their typically developing counterparts (Hermelin & O'Connor, 1967; Tager-Flusberg, 1991). Further evidence for reduced semantic processing in autism has been provided by studies investigating the ability to interpret individual words in the semantic context. In a seminal study, Frith and Snowling (1983) devised a homograph reading task to examine both semantic and syntactic competencies in hyperlexic children with and without autism. This was one of seven experiments designed to investigate reading abilities in hyperlexic children. The controls were children with dyslexia and typical development, matched for reading age. Homographs are words which have one spelling but several meanings, with the disambiguation occurring when correctly pronounced. The task was to read homographs, such as "tear" in context, e.g., "there was a big tear in her dress" versus "there was a big tear in her eye", presented in a story format. Five homographs were embedded into 10 sentences, and the children were not trained on the qualities of homographs prior to testing. The results from this experiment showed that the hyperlexic children with autism performed much worse than their reading age-matched controls with dyslexia. The authors concluded that the children with autism neglected to utilise the semantic context in order to disambiguate the homographs. Furthermore, the series of experiments showed that whilst children with autism exhibited intact phonological and lexical processing, they were specifically impaired in their ability to read for meaning compared to their matched controls. In an extension of this study, Snowling and Frith (1986) presented participants with 20 sentences with five embedded homographs. There were four different conditions: frequent versus rare pronunciation, and presentation either before or after the sentence context. A further modification concerned the procedure; a pre-test training session familiarising the children with double pronunciation of each homograph was included. The experimental hypothesis was that if the children utilised the semantic context of the sentences, then homographs that appeared after the target context word would be easier to pronounce correctly. Interestingly, the results showed no significant differences between the performance of children with autism, typically developing controls, and children with learning difficulties, matched for verbal mental age, suggesting that the children with autism showed normal semantic processing. However, in all three groups, only children with a verbal mental age of seven years or above utilised the semantic context in order to disambiguate the homographs, whilst children with lower verbal ability in all three participant groups were relatively uninfluenced by the semantic context.

Happé (1997) developed a hybrid paradigm using the materials from Snowling and Frith's (1986) study, but retaining the original open-ended format of their earlier (1983) experiment. Here, no pre-test training was given, and frequent and rare pronunciations of the homographs were required to be uttered either before or after the semantic context. The findings revealed that children with autism tended to show significantly reduced processing of the context-dependent meaning of the homographs compared to their matched, typically developing counterparts. This occurred even in conditions where the semantic context preceded the homograph, thereby providing a priming effect. These results present striking contrast to earlier findings by Happé (1994), where intact semantic processing had been observed. In this earlier study, participants were presented with "strange stories", and control questions were used to measure the children's understanding of the meaning of the texts. Interestingly, the findings showed that the participants with autism were able to process for meaning when explicitly directed to do so. However, whilst the results showed that children with autism *can* read for meaning, the findings from the homograph reading studies appear to suggest that reading for meaning is not the automatic mode of language processing in individuals with autism. Thus, importantly, it appears that whilst this capacity is available in autism (Happé, 1994; Snowling & Frith, 1986), processing language at the semantic level is not the default mechanism. Furthermore, it is interesting to note that there is neuropsychological evidence suggesting differences in the neural processing of semantic information between children with autism and those with typical development (Dunn, Vaughan Jr., Kreuzer, & Kurtzberg, 1999). In this study, children with autism and age-matched typical controls were presented with a semantic categorisation task in an auditory format, and their level of activation in a measure of semantic expectancy, the N4 potential, was measured. The stimuli consisted of individually presented words, of which half were animal labels, and the remaining half were unrelated non-animal words. The participants were asked to respond with a finger lift to the words belonging to the animal category. The results showed that the children with autism were slower and made more errors in classifying the target words than controls. Further, this group of children, unlike their controls, did not to show any difference in the N4 amplitude for target versus non-target words, suggesting that the categorical context (animal words) failed to establish an expectation for the target items.

Consistent with the reports of Kanner (1943; 1946) and Asperger (1944), prosodic abnormalities are commonly associated with the language disorder present in autism (see McCann & Peppé, 2003, for a recent review). For example, in the expressive domain, studies into linguistic prosody have typically reported such abnormalities as inappropriate and deviant use of intonation (e.g., Baltaxe, 1977; Baltaxe, Simmons, & Zee, 1984; von Benda, 1984; Bormann-Kischkel, Amorosa, & von Benda, 1993; Fosnot & Jun, 1999) and stress patterns (e.g., Baltaxe, 1984; Baltaxe & Guthrie, 1987; Baltaxe & Simmons, 1985; Fine, Bartolucci, Ginsberg, & Szatmari, 1991; McCaleb & Prizant, 1985). Sabbagh (1999) noted that individuals with autism tend to use prosody in an erratic fashion, and are particularly prone to produce prosody which carries no linguistic or communicative meaning. In one study, von Benda (1984) reported speech therapists' analyses of the prosodic features of the speech of children with autism and children with language impairment. The speech of the children diagnosed as autistic was associated with random and careless use of prosodic contours, to the extent that their use of affective prosody often contradicted the semantic content of the utterances. Fine et al. (1991) have suggested that children with autism may experience particular difficulties in tailoring their intonation to match the conversational contexts, suggesting that they may have difficulties with understanding the meaning conveyed by intonation in speech. Indeed, the communicative abnormalities seen in autism have been described as "extra-linguistic", since in addition to disordered prosody, they encompass impaired understanding of non-literal speech, jokes, irony, and the communicative intentions of others (Happé, 1993; 1994; Sabbagh, 1999).

As the acquisition of pragmatic competence is often conceptualised as the interface between social, cognitive, and linguistic development (Tager-Flusberg, 1997; 1999), the deficits in pragmatic understanding and communication appear to bear a close relationship with the non-verbal social abnormalities that are amongst the core features of autism. Kanner's (1943) description noted a lack of affective contact and interest in people, aloneness, an inability to relate to people, an unusual voice quality, and a failure to look at people's faces, but more strikingly, Asperger (1944) highlighted deficits in non-verbal communication as a core feature of the syndrome. Studies investigating joint attention behaviours in children with autism have found that the development of both protoimperative (instrumental or requesting function) and protodeclarative (sharing of awareness of an object or event) acts are impaired in autism, with the latter being more severely affected (e.g., Baron-Cohen, 1989; 1993; Mundy, Sigman, & Kasari, 1990; 1993). Longitudinal studies of children with autism have found positive associations between early joint attention abilities and later language development (e.g., Charman, 2003; Sigman & Ruskin, 1999; Stone & Yonder, 2001). Indeed, Charman (2003) has suggested that joint attention is one of the "pivotal" skills in autism. Consistent with these early social attentional abnormalities, Klin (1991) showed that five-year-old children with autism preferred to listen to a superimposed noise obtained from a busy canteen to their mother's voice. Similarly, another experiment found that five-year-old children with autism oriented more poorly to social than to non-social stimuli compared with children with Down syndrome and typical development (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998). The children with autism were matched to children with Down syndrome for verbal intelligence, language ability, and age, and to typically developing children only for verbal mental age. The orienting task consisted of social stimuli (hand-clapping and calling the child's name) and non-social stimuli (playing a musical box and rattle shaking). The results showed that whilst the children with autism exhibited a general deficit in orienting ability, their orienting towards social stimuli was specifically impaired compared to the two groups of control children. Perhaps the most influential theoretical account of autism, namely the theory of mind hypothesis, has integrated deficits in the communicative and social domains. This theory, pioneered by Uta Frith, Alan Leslie, and Simon Baron-Cohen, is based upon the assumption that a primary deficit in the fundamental human ability to attribute mental states to self and others can explain the triadic impairments that characterise autism (Baron-Cohen, Leslie, & Frith, 1985). More specifically, damage to one mechanism in the social brain is assumed to result in the core diagnostic deficits in pretend play, social functioning, and communication (Baron-Cohen, 1988; Leslie, 1987).

Research with typically developing children has consistently shown that the acquisition of a representational understanding of the mind occurs around the age of four years (e.g., Flavell, Flavell, & Green, 1983; Wellman & Bartsch, 1988; Wellman & Estes, 1986). This is to say that the ability to understand that the contents of a person's mind are not necessarily a reflection of reality, and not accessible to the minds of others, has been robustly linked to developmental changes that take place between the ages of three and four. The first empirical study testing the theory of mind hypothesis of autism used a false belief task (Baron-Cohen et al., 1985) that adopted a paradigm developed by Wimmer and Perner (1983). In this, children are presented with two dolls, Sally and Ann. The children's task is to predict where Sally will look for her marble which has been moved to a different location by naughty Ann, whilst she was out. The findings of Baron-Cohen et al. showed that 80 per cent of the children with autism, with a mental age of four years or above, predicted Sally's action on the basis of current reality rather than on the basis of her mistaken belief. A control group of children with Down syndrome with moderate intellectual impairment performed at a similar level to a control group of typically developing four-year-old children. These findings were taken as evidence that the mentalising ability was unrelated to intellectual ability, and was autism-specific. Subsequent experiments further supported the prediction that children with autism lack a theory of mind: such children failed to understand deception and when providing narratives of these kinds of stories, mentalistic terms such as "think" and "know" were virtually absent in their accounts (Baron-Cohen, Leslie, & Frith, 1986). A large body of research using a range of paradigms has since replicated Baron-Cohen and colleagues' finding of theory of mind impairment in autism (see Baron-Cohen, 2000, for a review). Although the main body of this work has concentrated on examining the cognitive developments that are associated with the acquisition of the representational understanding of mind (Baron-Cohen, 2000), some studies have incorporated a linguistic framework (Happé, 1993; 1994; Tager-Flusberg, 1992), whereby the implications of the inability to understand mental states of self and others have been related to everyday social and communicative functioning (Frith, Happé, & Siddons, 1994). Taken together, this research indicating a theory of mind deficit in children with autism provoked suggestions that false-belief tasks might be a useful diagnostic of autism, and that autistic behaviour might be entirely explained by "mind-blindness" (Baron-Cohen, 1988; Baron-Cohen et al., 1985).

More recently, researchers have pinpointed several shortcomings in the theory of mind hypothesis. Firstly, a number of studies have drawn attention to the fact that many young individuals with autism do succeed in theory of mind tasks, and therefore these tests cannot be diagnostic of autism (Charman, 2000). Furthermore, the autism-specificity of theory of mind impairments has become highly controversial; for example, young individuals with intellectual impairment (Yirmiya, Erel, Shaked, & Solomonica-Levi, 1998), blindness (Brown, Hobson, Lee, & Stevenson, 1997), and deafness (without having signing parents) (e.g., Peterson & Siegal, 1995) have been shown to fail standard theory of mind tests more often than would be expected on the basis of their age and developmental stage. Secondly, the concept of theory of mind and the nature of the tasks used to measure it have been severely criticised (see Klin, 2000). For example, the "all-or-nothing" nature of many theory of mind tests neglects the fact that such abilities are likely to be dimensional rather than dichotomous. Furthermore, the tasks are presented in an explicit, verbal, problem-solving format, which bears little resemblance to naturalistic social situations. A related problem concerns the fact that the level of verbal ability has been shown to correlate strongly with children's performance in the theory of mind tasks (e.g., Bowler, 1992; Eisenmajer & Prior, 1991; Happé, 1995; Yirmiya et al., 1998), and that individuals with ostensibly profound social deficits have been shown to succeed in theory of mind tasks of variable complexity, without showing corresponding levels of spontaneous social adaptation (e.g., Bowler, 1992; Dahlgren & Trillingsgaard, 1996; Klin, 2000). It has been suggested that rather than reflecting true, qualitatively equivalent social competence to typical individuals of the same age, intellectually able persons with autism can "hack" out solutions (Happé, 1995; Happé, Ehlers, Fletcher, Frith, Johansson, Gillberg, Dolan, Frackowiak, & Frith, 1996) to such tasks using general reasoning and verbal skills. Finally, researchers have raised concern about the age at which autism is diagnosed in relation to theory of mind abilities. The majority of the research into theory of mind in autism has investigated abilities that are apparent in typical development at approximately the age of four. This is problematic given that the symptoms of autism must be present *before* the age of three (APA, 1994; WHO, 1992), and therefore symptoms of autism are present long before the emergence of a representational theory of mind (Tager-Flusberg, 2001a). Indeed, there is substantial evidence to show that a reliable diagnosis of autism could be given at the age of two (Lord, 1995; Moore & Goodson, 2003), on the basis of measures of early social responsiveness, such as play, joint attention, and imitation. However, not all such measures implicate theory of mind; for example, early social responsiveness only entails the acknowledgement of another person's presence, or the responding to someone's behaviour (Klin & Volkmar, 1993), and clearly an absence of such behaviours does not necessarily implicate a lack of theory of mind (Tager-Flusberg, 2001a). Furthermore, it is difficult to tell whether a primary deficit in early social behaviours, such as in joint attention, might result in a developmental trajectory whereby theory of mind fails to develop, or whether a lack of theory of mind is caused by damage to an innate theory of mind module (Happé, 2001), and abnormalities in these earlier behaviours reflect such impairment. In either case, the outcome would give rise to marked deficits in the domain of social attention (Ibid.).

A modern extension of the theory of mind hypothesis, that has attempted to overcome some of the criticisms discussed above, is based upon the notion that the emergence and development of theory of mind is a result of developments in several interacting components involved in social information-processing, as opposed to just one "theory of mind module". Known as the componential model of theory of mind, this model makes a distinction between a basic social-perceptual component and its associated specialised underlying mechanisms, and a more advanced social-cognitive component, of which only the latter is measured by the traditional theory of mind tests (see Tager-Flusberg, 2001a; Tager-Flusberg & Sullivan, 2000). The social-perceptual component refers to immediate, on-line judgements of a person's mental state derived from facial expressions, speech prosody, posture, and body language. Developmentally, the social-perceptual component is thought to build upon the innate preference of infants to attend to human social stimuli such as facial expression, voice, and eye gaze (e.g., Mehler & Dupoux, 1994), whereby the social preferences of infants drive and promote developments in acquiring the understanding of mental states (e.g., Baldwin, 1993; Baron-Cohen, 1994). Due to an early lack of interest in social stimuli (Dawson et al., 1998; Klin, 1991), deficits in this component in children with autism could be expected to be present early on in development, and manifested in areas such as joint attention (e.g., Mundy, Sigman, & Kasari, 1990; 1993). In contrast, the social-cognitive component refers to the ability to generate complex cognitive inferences, achieved by the integration of information over time about the content of people's mental states.

This component is assumed to be intimately related to other cognitive or information-processing systems, such as language and memory. As the social-cognitive component is hypothesised to build upon the earlier developments in the social-perceptual domain, impairments highlighted by theory of mind research could also be expected in this system in autism (Baron-Cohen, 2000). This broader theory of mind model has considerably more explanatory power than the original theory of mind hypothesis. Firstly, this model conceptualises theory of mind abilities as dimensional rather than categorical. This is an important distinction in the light of the evidence showing that success in the traditional dichotomous theory of mind tests do not correspond to spontaneous social adaptation in individuals with autism (e.g., Klin, 2000). Secondly, by separating perceptual abilities from linguistic competencies, theory of mind abilities can be examined in a more perceptual, and less linguistic, format. Several new tests of social cognition have been developed, which have been specifically designed to avoid an explicitly verbal, problem-solving format. Examples of such tasks include the eyes task (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997), the parallel voices task (Kleinman, Marciano, & Ault, 2001), and the social attribution task (Klin, 2000). Thirdly, this model allows the examination of developmental asynchronies between theory of mind abilities and competencies in other cognitive domains (Tager-Flusberg, 2001a). Thus, subtle qualitative and quantitative differences between children's theory of mind abilities and the underlying mechanisms that tap into different aspects of theory of mind competence can potentially be investigated within this framework. Furthermore, this model highlights the importance of understanding the relationship between perceptual and social-cognitive abilities. In this thesis, theory of mind abilities will be broadly referred to as "social-cognitive" or "meta-representational" abilities, to distinguish between the narrower assumptions of the original theory of mind hypothesis and the more recent, wider conceptualisation of such functions.

A model of human communication and cognition that has been successfully applied to the communicative impairment in autism is Relevance theory (Sperber & Wilson, 1995). Only a brief summary of this theory will be given here, as a more detailed account will be provided in chapter seven of this thesis. As is evident from the research reviewed above, individuals with autism are considered to show a fundamental deficit in the ability to attribute mental states to themselves and others (e.g., Baron-Cohen et al., 1985). As the core assumption of Relevance theory states that the ability to attribute intentions to others is a fundamental characteristic of human communication (Sperber & Wilson, 1995, p.23), it thus follows that the theory of mind deficits in autism would manifest as a reduced use of language for communication. One of the basic premises of Relevance theory is the distinction between the meaning of sentences (semantics) and the communicative meaning (pragmatics) conveyed by utterances. These are termed as the informative intention, which refers to the literal, informative meaning of the utterances, and the communicative intention, namely to inform someone about one's intention to inform. It is specifically assumed that the difference between these types of meaning is that communicative meaning requires inference, whilst the informative type does not. Thus, in order to understand the communicative meaning of utterances, listeners must be able to represent the speaker's intention. As intentions are mental states, this theory allows explicit predictions to be made about the communicative abilities of individuals with no theory of mind, with first-order theory of mind only, and with second-order theory of mind ability. According to Relevance theory, understanding of literal, informative intention requires first-order theory of mind ability, whilst the comprehension of communicative intention is a second-order process. It is also noteworthy that this theory further assumes that human information-processing is chiefly driven by relevance; in other words, individuals automatically process information that is relevant to them. Intentional communication is recognised as relevant due to the fact that it is ostensive (i.e., it provides evidence of one's thoughts). Evidence has shown that young children with autism demonstrate substantially reduced orientation towards human social stimuli (Dawson et al., 1998; Klin, 1991) which seems likely to result in disruption of growing abilities to understand the social signals of others. Thus, what is recognised as "relevant" by individuals with autism may be very different to the information regarded as such by those with typical development.

Francesca Happé (1993) successfully applied Relevance theory framework in a study where the level of theory of mind ability of children with autism was directly related to their ability to understand utterances expressing simile, metaphor, and irony. The stimuli had three levels of difficulty. First were similes, which are literal and involve no intention, therefore requiring no theory of mind ability. Second were metaphors that involve some intention, and thus require first-order theory of mind reasoning to be understood. Third was irony, which requires second-order theory of mind ability to be accurately comprehended as the literal meaning contradicts the communicative intention. The findings from this study indicated that the children's level of theory of mind ability explicitly predicted their level of communicative competence. Thus, whilst only the children with second-order theory of mind ability were able to understand all three types of utterances, the children with no theory of mind ability only understood similes. This study showed that Relevance theory could be fruitfully applied to deepen our understanding of the communication disability in autism. More specifically, it provides a framework whereby variable levels of communicative competence can be mapped onto the underlying abilities to understand different kinds of intention. Subsequently, Frith and Happé (1994) hypothesised that semantic processing deficits in autism might also be associated with such individuals' difficulties in understanding the communicative intentions of others.

In contrast to the theory of mind hypothesis, the executive functions theory of autism (Pennington, Rogers, Bennetto, Griffith, Reed, & Shyu, 1997; Russell, 1997) posits that the triadic deficits in autism result from impairments in executive control mechanisms that are domain-general, and thus are not specific to the social domain (see Hill, 2004; Joseph, 1999, for reviews). Executive functions deficits are typically seen in patients with acquired frontal lobe damage, as well as individuals with a range of neurodevelopmental disorders, that implicate a congenital impairment in the frontal lobes (Hill, 2004). Patients with acquired frontal lobe damage typically show behavioural and cognitive rigidity and perseverance with routines, explained by an inability to initiate new actions and difficulties in disengaging from a given task set. "Executive function" is an umbrella term used to refer to interacting, but potentially dissociable functions. These are functions needed to disengage from the immediate context to guide behaviour, such as planning, working memory, impulse control, inhibition, and monitoring of action (Hill, 2004; Stuss & Knight, 2002). It has been suggested that this theory might be best used to explain such features of autism as repetitive, stereotyped, and rigid behaviour patterns, and a restricted range of interests (Hill, 2004). It is interesting to note, however, that the executive functions account of autism was originally formulated as an alternative to the theory of mind hypothesis. The executive function model explains the core deficits in autism in communication and social functioning as a failure in on-line updating, in evaluation, and in selection of relevant responses to a continuous flow of verbal, non-verbal, and contextual information (Bennetto, Pennington, & Rogers, 1996; Hughes & Russell, 1993). The supporters of this theory have argued that the deficits in executive functions could potentially be more fundamental than those seen in theory of mind function in autism, and thus might explain such impairments (Pennington et al., 1997; Russell, 1997). Two lines of evidence have been taken as support for this argument: firstly, studies have shown that individuals with autism have been more successfully identified on the basis of their performance in executive function tasks than that in theory of mind tests (Ozonoff, Pennington, & Rogers, 1991). Secondly, that performance in these two measures is positively associated in autism (Ozonoff et al., 1991; Russell, Mauthner, Sharpe, & Tidswell, 1991). A recent study addressed the relationship between theory of mind and executive functions in relation to symptom severity and symptom type in children with autism (Joseph & Tager-Flusberg, 2004). The findings showed that, whilst both theory of mind ability and executive functioning explained the variance in children's communication abilities beyond that of their language skills, neither ability accounted for the substantial variance in reciprocal social interaction and repetitive symptoms when language ability was accounted for. The authors suggested that social functioning in autism might be more closely associated with social-perceptual abilities, as described by the componential model of theory of mind (Tager-Flusberg & Sullivan, 2000), rather than the cognitive-linguistic and related executive function abilities. However, using a range of different tasks of executive function, studies have reported deficits in individuals with autism in many areas, such as planning (Ozonoff et al., 1991; Ozonoff & Jensen, 1999), the inhibition of a prepotent response (Hughes & Russell, 1993), and perseveration or mental flexibility (Bennetto et al., 1996; Ozonoff, 1995; Ozonoff et al., 1991). Thus, there is at least some evidence that individuals with autism show impairments in executive functions. Nevertheless, several shortcomings have been highlighted in this theory. The first criticism concerns a lack of agreement regarding the aspects of executive dysfunction typical of autism. A small number of studies have not found executive function deficits in such individuals (Baron-Cohen, Wheelwright, Stone, & Rutherford, 1999; Hill & Russell, 2002; Minshew, Goldstein, Muenz, & Payton, 1992; Russell & Hill, 2001). In order to be considered as a diagnostic marker, such deficits should be a universal feature in autism (Hill, 2004). A related problem is that executive function deficits have been identified in neurodevelopmental disorders other than autism, for example, in attention deficit hyperactivity disorder (ADHD) (Pennington & Ozonoff, 1996). Although studies have found distinct patterns of dysfunction in autism that distinguishes it from the deficits seen in other disorders, for example, ADHD (Ozonoff & Jensen, 1999; Pennington & Ozonoff, 1996), the question of whether executive function deficits are a valid diagnostic marker for autism remains unanswered. In ADHD, planning deficits are markedly milder than those seen in autism. However, Hill and Frith (2003) argue that the executive function theory is potentially of great value for individuals with autism, as the alleviation of such difficulties can help to improve the independent every-day functioning of such individuals.

A cognitive profile that is characteristic of autism encompasses an uneven pattern of abilities and deficits. Given the nature of the disorder, the areas where individuals with autism show "preserved" abilities almost universally lie in the non-social domain. Assuming the theory of mind hypothesis, and the triadic impairments in autism arise from a primary impairment in mentalising ability, it could indeed be expected that there would be areas of preserved skill (Happé, 1999). Of particular relevance to this thesis are preserved skills that relate to auditory processing abilities in individuals with autism. It is of interest to note here that even in the seminal description of autism, Kanner (1943) made frequent references to preserved musical abilities amongst the children he studied. For example, one boy could "hum and sing many tunes accurately" (Kanner, 1943, p.217) at the age of just one year. Similarly, another boy with very little speech could sing about twenty or thirty songs, including a little French lullaby, at the age of two-and-half years. Most striking appear to be the abilities of a boy, who, at the age of one-and-half years, "could discriminate between eighteen symphonies. He recognised the composer as soon as the first movement started" (Ibid., p.236). Since Kanner, researchers have noted that children with autism often prefer, and show greatly superior skill, in expressing themselves verbally through music (singing) than through speech (Jolliffe, 1992; Thaut, 1988). Similarly, in the receptive domain, Blackstock (1978) noted that children with autism preferred to listen to music over speech, whilst control children failed to show any preference. This distinction is important in the light of this thesis, especially as speech and music share significant acoustic features. It is of relevance to note that such acoustic properties as pitch and pitch contour serve significant functions in speech, where such parameters modulate prosody. Acoustically, prosody is manifested by, but not limited to, variations in fundamental frequency, amplitude, and duration (Lehiste, 1970), with the most significant prosodic effects being produced by the linguistic use of pitch, or intonation (Lieberman, 1960). Consistent with the earlier reports, a recent line of behavioural evidence has highlighted enhanced musical pitch discrimination and pitch memory abilities in autism (Bonnel, Mottron, Trudell, Gallun, & Bonnel, 2003; Heaton, 2003; Heaton, Hermelin, & Pring, 1998; Heaton, Pring, & Hermelin, 1999). For example, in an early pitch discrimination and memory study, Heaton and colleagues (1998) presented musically untrained children with autism with four pitches and four word-fragments to be matched to animal pictures. Whilst the findings showed no group differences in performance with matching the word-fragments to pictures, the children with autism showed significantly higher levels of performance in the pitch task compared to their age- and intelligence matched controls. Strikingly, when recall was tested after seven days from the initial exposure, the children with autism recalled more pitch/animal pairs than did their controls after just two-and-a-half minutes.

The studies cited above, together with Kanner's descriptions of the children with autism, highlights the fact that whereas some abilities may merely be "preserved" in autism, there are individuals who show highly superior skills, termed "savant" or "splinter" abilities. It has been estimated that one in 10 individuals with autism possess some kind of savant ability (Treffert, 2000). These abilities have been recognised, for example, in the areas of music, art, calculation, and memory (see Heaton & Wallace, 2003, for a review). Happé (1999) noted that these abilities could not be easily explained within the framework of "deficit" accounts of autism, such as the theory of mind hypothesis and the executive function account. More specifically, these models fail to explain why some individuals with autism should show not only preserved, but enhanced abilities in certain areas. One influential non-social account of autism, which has attempted to explain the puzzling co-occurrence of talents and deficits, is the weak central coherence theory (Frith, 1989a; later revised by Happé, 1999). Here, the mind is considered to be merely different, as opposed to "deficient", in autism. Frith assumed that a single cognitive cause, that of "weak central coherence", was responsible for the uneven cognitive functioning in autism. Central coherence refers to the typical tendency to process information in context, and to integrate information for high-level meaning, often at the cost of attention and memory for detail. Consistent with this, at least in some areas of perception, global processing has been shown to predominate over local processing in typical individuals (Kimchi, 1992; Navon, 1977). By contrast, individuals with autism are assumed to exhibit "weak" central coherence, manifested in a tendency to attend to local, rather than global, aspects of both verbal and non-verbal perceptual information. Consequently, reduced processing for global configuration and contextualised meaning would be expected. It thus follows that the weak central coherence theory predicts that individuals with autism would show high levels of performance in tasks requiring attention to local details, whilst their performance in tasks requiring the processing of information in context, or for a global meaning, would be compromised (Happé, 1999). Due to the superior performance of individuals with autism in some tasks, Happé (1999) argued that this information processing approach is better conceptualised as a cognitive style rather than a cognitive deficit.

The weak central coherence theory predicts that the detail-focused perceptual processing style should manifest in all sensory modalities. Furthermore, weak central coherence in autism has been described at various levels of complexity (Happé, 1999). Much of the earlier work testing this hypothesis was carried out using visual tasks where the tendency towards weak central coherence may be seen as advantageous, such as the block design subtest of the Wechsler Intelligence Scale (Wechsler, 1992; 1997), and the embedded figures test (Witkin, Oltman, Raskin, & Karp, 1971). The findings from several such experiments have shown that individuals with autism tend to outperform their age-matched controls without autism (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983; 1993). Later studies have shown that, for example, individuals with autism show heightened sensitivity to unique features of stimuli, whilst they have difficulties with recognising similarities between stimuli (Plaisted, O'Riordan, & Baron-Cohen, 1998), and that such individuals show difficulties in detecting visually induced coherent motion (Milne, Swettenham, Hansen, Campbell, Jeffries, & Plaisted, 2002). These findings may be taken as evidence of the presence of weak central coherence at the "low" visual-perceptual level in autism.

As was mentioned previously, the weak central coherence theory assumes that individuals with autism will show a marked disadvantage in tasks that require information to be integrated in a context-dependent fashion. Examples of such tasks were used in the homograph reading experiments (Frith & Snowling, 1983; Happé, 1997), cited earlier. As the results of these studies showed that children with autism were significantly more likely than their matched controls to neglect the semantic context, whilst attempting to disambiguate the meaning of the homographs, as compared to typical controls, Happé (1999) interpreted these findings as evidence for the presence of weak central coherence at the "high" verbal-semantic level. Further support for this has been derived from memory studies (Hermelin & O'Connor, 1967; Tager-Flusberg, 1991), indicating that individuals with autism show a reduced tendency to organise verbal information according to semantic categories.

Although relatively little research has been carried out in the area of auditory perception, Happé (1999) cited evidence of the high occurrence of absolute pitch abilities in autism (Heaton et al., 1998) as evidence for auditory weak central coherence. Furthermore, Heaton and colleagues (1999) have argued that the exceptional musical abilities found in some individuals with autism are associated with a featurally-biased, analytical information-processing style. A recent line of research has attempted to clarify the presence in autism of weak central coherence in auditory perception. Four studies, employing an analogous paradigm, tested musically naïve individuals with autism in a contour discrimination task (Foxton, Stewart, Barnard, Rodgers, Young, O'Brien, & Griffiths, 2003; Heaton et al., 1999; Heaton, in press; Mottron, Peretz, & Ménard, 2000). The stimuli were pairs of short melodies that were either (1) the same, (2) included a one tone alteration that maintained the Gestalt characteristics of the original melody, or (3) included a one tone alteration that violated the Gestalt characteristics of the original melody. In the first study to utilise this paradigm, Heaton et al. (1999) found an enhanced ability to detect changes in contour-maintaining melody pairs in an adolescent boy with Asperger syndrome, a finding that was subsequently confirmed in a group study by Mottron and colleagues (2000). Although Heaton and colleagues had interpreted their findings as providing support for the WCC theory, Mottron et al. suggested that an absence of group differences in performance with the same melody pairs meant that normal "global" processing was in evidence in the autism group, and that this disproved the WCC hypothesis. Subsequent studies employing the contour paradigm have found a different pattern of performance. For example, Foxton et al. (2003) presented participants with autism with a contour discrimination task, and failed to find evidence of superior detection of interval-changed tones in contour-maintaining pairs of melodies. However, when the authors presented the same participants, who might be expected to show normal global processing, with a task that involved the integration of different musical components, performance between autism and control groups was qualitatively different. Foxton and colleagues interpreted their findings as being consistent with the WCC hypothesis in that the participants with autism were not susceptible to interference from an auditory global whole. In the last of the four contour studies, Heaton (in press) found that whilst children with autism failed to show enhanced discrimination of changed pitch intervals embedded within contours, their ability to discriminate disembedded pitch intervals was significantly superior to that of age- and intelligence matched controls. Heaton (in press) concluded that in autism, both local and configural processing are enhanced or intact. It remains to be seen to what extent global processing deficits are in evidence in the musical domain.

The problems with the weak central coherence theory outlined above have resulted in alternative proposals for the mechanism underpinning the enhanced local level processing in autism. These theories build upon the evidence suggesting that individuals with autism are able to respond to the global level of information normally in some situations (e.g., Happé, 1994; Heaton, in press), and that in some instances, such individuals show faster and more accurate processing of low-level perceptual stimuli than their controls (Mottron & Belleville, 1993; Plaisted, Swettenham, & Rees, 1999). Furthermore, as these new models are purely limited to perception, they do not make any predictions about deficiencies in higher-level processing in autism, as such processes would depend upon post-perceptual mechanisms such as integration and grouping (see Palmer & Rock, 1994, for a discussion). To account for the findings from the contour discrimination studies (Heaton et al., 1999; Mottron et al., 2000), Mottron and Burack (2001) proposed the enhanced perceptual functioning (EPF) theory of autism. This model builds upon an earlier hierarchization deficit hypothesis put forward by Mottron and Belleville (1993). Here, both the local and global processes are assumed to be intact in autism, but the abnormality lies in the interaction between local and global processes. More specifically, this model suggests that the perception of the global whole does not interfere with the perception of the detailed local features of the stimuli to the same extent as would be the case in typical individuals. Thus, the interaction between the local and global processes is abnormal. The EPF theory posits that the enhanced pitch discrimination in autism results from disproportional over-development of low-level perceptual functions. It is suggested that such "over-development" stems from an early developmental bias in such individuals to attend to low-level perceptual stimuli, and that as a result, this development compensates for specific cognitive impairments. Consequently, processing mechanisms involved in the detection, discrimination, and categorisation of perceptual stimuli are assumed to be enhanced in autism. Subsequently, some capacities for higher-level processes are over-ridden, as low-level perceptual information dominates the attentional resources in autism. One manifestation of this would be superior performance in the pitch processing tasks discussed above. A shortcoming of this theory concerns the difficulty with formulating testable hypotheses to examine, for example, the "over-development" of low-level perceptual processes in early development.

Another alternative to the weak central coherence theory has suggested that the abnormal perceptual processing in autism results from an enhanced salience of unique stimulus features, which do not compromise global configural processing (Plaisted, 2001). Known as the reduced generalisation model of autism, this account posits that autism is characterised by a processing style in which individual stimulus features are presented with high acuity, stemming from the capacity of such individuals to form unusually finely-tuned perceptual representations. However, one consequence of this processing style is decreased recognition of similarities or shared features between different stimuli and situations, leading to reduced generalisation and categorisation of stimuli. Poor generalisation and categorisation ability have been commonly observed in autism, for example, in the linguistic domain (Kanner, 1943; Tager-Flusberg, 1991). This theory makes two explicit predictions about perceptual processing in individuals with autism: firstly, that such individuals will exhibit enhanced discrimination of stimuli that are highly similar to each other, and secondly, that they will show correspondingly poor categorisation ability of two sets of different stimuli. This processing style is assumed to impinge upon all levels of psychological processing, including the higher-level language domain. Much of the empirical work testing this theory has been carried out using visual tasks. Evidence for reduced generalisation was found, for example, in a difficult perceptual learning task, where both the target items and accompanying distractors shared highly similar perceptual features (Plaisted et al., 1998). Here, at first, two stimuli appear identical, but with prolonged exposure, become distinguishable from one another. Hence, the shared features between the two stimuli become less salient with exposure, enabling the unique features of the stimuli to become relatively more conspicuous. One experimental condition involved the discrimination of two highly similar stimuli that had been pre-exposed, and another condition introduced two stimuli that were entirely novel. The results showed that whilst normal controls showed the anticipated learning effect of performing better with the pre-exposed stimuli, the adults with autism not only failed to show any difference in discriminating between the pre-exposed and the novel stimuli, but that they outperformed the controls in the novel discrimination task. These findings were taken as evidence that individuals with autism treated both of the stimuli types as unique, a processing style that is assumed to result from a deficit in processing perceptual similarities between stimuli. One study attempted to test whether the acute feature representation might generalise to the auditory domain (Plaisted, Saksida, Alcántara, & Weisblatt, 2003). This study employed a paradigm whereby the auditory selectivity of participants with autism was assessed.

Based upon earlier work showing that individuals with autism experience problems in speech perception in the presence of background noise (Alcántara, Weisblatt, Moore, & Bolton, 2004), together with superior musical pitch discrimination ability (e.g., Heaton et al., 1998; Mottron et al., 2000), the authors hypothesised that such individuals might show greater than normal auditory selectivity. If individuals with autism possessed greater than normal acuity in their representation of auditory information, this might be expected. However, contrary to the hypothesis, the findings showed that the auditory filters in participants with autism were wider than those observed in typical individuals. Thus, these results suggest, interestingly, that the auditory filters in individuals with autism were similar to those with hearing impairment, indicating deficits in the early stages of auditory processing. Accordingly, one implication of this is that, in order to hear a signal, individuals with autism require a greater discrepancy in frequency between the signal and background noise than do those with typical development. These findings are intriguing in the light of the studies showing enhanced auditory discrimination abilities in the musical domain in autism. The authors suggested that one possible explanation for this discrepancy was that the enhanced featural processing in autism might occur at the later processing stages when the perceptual representations are formed. Another possibility is that this discrepancy reflects a speech-selective auditory processing deficit in autism.

It has become apparent from the studies cited in this introduction that there is a marked disparity between the processing abilities in the linguistic and musical domains in autism. Although the neurofunctional deficits underlying this pattern of behaviour are not yet fully understood, studies into auditory processing in autism have reported abnormalities at the biological level. Recently, two neurological studies have directly compared the patterns of brain activity in response to both speech and music in participants with autism and typical controls. In one such investigation, Čeponienė and colleagues used cortical event-related brain potentials to measure activation due to vowel and pitch stimuli (Čeponienė, Lepistö, Shestakova, Vanhala, Alku, Näätänen, & Yaguchi, 2003). The measurements taken were as follows: auditory sensory ERPs, assumed to signal sound intensity or frequency; the mismatch negativity component, thought to show detection of infrequent "deviant" sounds as distinct from repetitive "standard" sounds; and the P3a component, assumed to show the involuntary switch in attention towards salient events in the environment. The results failed to show any significant differences in the auditory sensory ERPs and mismatch negativity to the pitch stimuli across the participant groups. Strikingly, however, the children with autism, in contrast to their typical controls, showed no detection of changes in vowel pitch, although they did so for tones. The authors suggested that this finding might reflect a speech-specific attentional deficit in autism in orienting towards the "speechness" quality of sounds. In a similar vein, in an investigation using positron emission tomography (PET), Müller et al. found abnormalities in the brain mapping for not only speech, but also for musical tones, in adults with autism (Müller, Behen, Rothermel, Chugani, Muzic, Mangner, & Chugani, 1999). More specifically, atypical functional asymmetry for both speech and tonal stimuli was seen for participants with autism. These individuals, contrary to controls, showed reduced left hemispheric involvement during verbal stimulation, and activation in the left anterior cingulate gyrus in response to the tonal stimuli. Consistent with this, a functional magnetic resonance imaging (fMRI) investigation found abnormal cortical activation during the processing of socially relevant auditory information in individuals with autism (Gervais, Belin, Boddaert, Leboyer, Coez, Sfaello, Barthélémy, Brunelle, Samson, & Zilbovicius, 2004).

Here, cortical activation patterns of adults with autism and typical controls in response to vocal speech sounds and non-vocal environmental sounds were compared. Whilst the findings failed to reveal any abnormalities in the adults with autism, relative to their controls, in the perception of non-vocal sounds, these participants failed to show activation in the voice-selective regions of the cortex in response to the vocal sounds. Furthermore, when the participants were requested to recall the sounds heard immediately after the scanning procedure, the individuals with autism recalled significantly fewer vocal sounds than the controls, this proportion being just eight-and-one-half per cent of the total number of sounds listed. Whilst there was no significant difference between the groups in the total number of sounds recalled, the controls enumerated an equal number of vocal (51%) and non-vocal (49%) sounds. Taken together, these studies suggest a selective impairment in orientation towards, and processing of, speech sounds in autism. Gervais and colleagues suggested that there may be an attentional bias towards non-speech information in autism, resulting in the enhanced processing of linguistically meaningless pitch.

As has become apparent, the theories discussed above offer very different cognitive explanations for the core impairments of autism. Hill and Frith (2003) suggested that it would be wrong to regard them as rivals to each other, as each can explain unique cognitive deficits in autism. The recent view, however, is that, for example, theory of mind deficit and the weak central coherence cognitive style stem from separate underlying cognitive causes, but that theory of mind functions need to be fed by contextual central coherence information (Happé, 2001). One difficulty with the theories presented so far in this introduction concerns the fact that they do not account for the various subgroups of autism. Now that an increasing number of studies are highlighting the existence of the broader autism phenotype in each of the three core areas of dysfunction (see Bailey et al., 1998, for a review), there is an increasing need to explain a wider range of performance, abilities, and deficits. For example, although exceptional pitch discrimination skills have been reported in some studies (e.g., Heaton et al., 1998; Heaton et al., 1999; Mottron et al., 2000), enhanced musical abilities are the exception rather than rule in autism (Foxton et al., 2003). Indeed, in a recent, more stringent test of pitch, memory, discrimination, and generalisation, Heaton, Happé, Williams, and Cummins (under review) found that approximately 10 per cent of their sample of children with autism showed outstanding pitch processing abilities. Furthermore, whilst the weak central coherence hypothesis, the enhanced perceptual functioning model, and the reduced generalisation theory predict that a shift towards perceptual or featural processing is crucial for the development of exceptional skills, it has been suggested that individuals with special skills may represent a genetically distinct subgroup (Nurmi, Dowd, Tadevosyan-Leyfer, Haines, Folstein, & Sutcliffe, 2003). Pertaining to the identification of the broader phenotype of autism, a current trend in research is the attempt to identify homogeneous subgroups based on genetic and phenotypic characteristics of individuals within the autism spectrum (e.g., Prior, Leekham, Ong, Eisenmajer, Wing, Gould, & Dowe, 1998; Tager-Flusberg & Joseph, 2003). At the same time, some researchers have turned their attention to models of typical development in order to illuminate the ways in which the developmental trajectory in autism might be different, and what the subsequent "down-stream" developmental effects might be.

One important recent theory that can potentially tie together the deficits in the social-linguistic domains and the enhanced perceptual processing abilities in autism is the enactive mind model (Klin, Jones, Schultz, & Volkmar, 2003). Building upon the findings that social stimuli have markedly reduced salience for children with autism as compared to those with typical development (Dawson et al., 1998; Klin, 1991), this theory posits that the developmental trajectory in autism leads to enhanced specialisations being formed in a range of physical stimuli instead of in the social domain. This is because, in typical development, perceptual processes are considered to be highly specific, sensitive, and active in seeking salient stimuli to focus upon. Social stimuli are considered to be substantially more salient than competing non-social information because of their survival value (Bates, 1979; Klin, Schultz, & Cohen, 2000). This relates to the issue of relevance in autism, as the reduced salience of socially relevant stimuli is postulated to result in a "cascade of developmental events" whereby a child with autism will fail to perform appropriately in the social world. Furthermore, cognition is seen as "embedded in experiences resulting from a body's actions upon salient aspects of its surrounding environment" (Klin et al., 2003, p.357). It thus follows that social cognition is defined as the actions and experiences that are specifically associated with social interaction. It is postulated that in autism, social information is acquired and constructed outside the social domain, due to the fact that "foundational" experiences are not within this domain. Crucial supporting evidence for this model is derived from studies showing a substantial discrepancy between what individuals with autism are capable of doing in explicit tasks of social reasoning, such as theory of mind tests, and what such individuals are able to do spontaneously in naturalistic social situations (Bowler, 1992; Klin, 2000; Klin et al., 2000). As was mentioned before, individuals with autism with ostensible social impairments have been shown to succeed in theory of mind tasks of variable levels of difficulty, without showing corresponding levels of social adaptation (e.g., Klin, 2000). Even more important is evidence from studies that have compared social orientation behaviours in autism and typical development in response to viewing dynamic social scenarios. Klin and colleagues carried out a series of eye-tracking experiments using a technique that allows the assessment of a person's visual focusing points when viewing complex social scenarios (Klin, Jones, Schultz, Volkmar, & Cohen, 2002a; Klin, Jones, Schultz, Volkmar, & Cohen, 2002b). In one such study, participants were played a video of a dramatic social situation involving several protagonists (Klin et al., 2002b). Whilst, during one scene, the typical controls focused immediately on a look of horror and surprise in one of the character's eyes, the participants with autism fixated on the man's mouth region, which was virtually expressionless. The data analysis showed that, whilst typical controls, in attempting to understand the situation, focused on the eye-region, some participants with autism converged on the mouth regions or to areas peripheral to the face. A striking finding was that whilst the participants with autism fixated on the mouth region of faces twice as much as the controls, the controls focused on the eye region two-and-a-half times more often than those with autism. Another study measured a joint attention skill that involves following a pointing gesture, whereby a target is identified by the direction of pointing (Mundy & Neal, 2000) (Klin et al., 2002a). According to the authors, the emergence of this developmental landmark is operational around the age of 12 months in typical infants. Using the same video as in the experiment described earlier, one scene showed a man who is interested in a painting that hangs on the wall. This is expressed by first pointing to the specific picture which hangs alongside several others, followed by a question about the painter of the picture. The visual scanning paths of the participants showed that the typical participants followed the pointing gesture immediately to the correct picture, and after his question, referred back to the responding protagonist, and then back again to the actor who asked the question for his reaction. By contrast, the participants with autism failed to follow the pointing gesture, waited for the question, and then scanned each of the pictures without appearing to understand which one the conversation concerned. Thus, it appeared that the participants with autism relied primarily on the verbal information which resulted in their having a poor grasp of the situation. Interestingly, when the participants with autism were tested afterwards for their understanding of the pointing gesture in an explicit fashion, they had no difficulty in explaining its meaning. The authors subsequently hypothesised that individuals with autism acquire social understanding in an atypical fashion, which may be a downstream effect of the developmental trajectory whereby the salience of socially relevant stimuli is substantially reduced.

A number of theorists have recently applied connectionist neural network models to cognitive development in an attempt to explore how different initial constraints in the cognitive system can interact with an environment to produce behaviours that are present in typical development (Elman, Bates, Johnson, Karmiloff-Smith, Parisi, & Plunkett, 1996; Mareschal & Thomas, 2000). Subsequently, these models have been extended to atypical populations in a quest to explore how shifts in the initial constraints might bring about the abnormal behaviours that are found in abnormal development (see Karmiloff-Smith & Thomas, 2002). For example, connectionist models have been used to explain the atypical perceptual discrimination abilities in autism (Cohen, 1994; Gustaffson, 1997), and to examine the emergence of abnormal cortical maps applying a neurobiologically constrained model (Oliver, Johnson, Karmiloff-Smith, & Pennington, 2000). Such models are founded upon the notion of modularity of the cognitive architecture (e.g., Fodor, 1983), for which findings from studies of adults with selective brain damage have been cited as evidence. Such findings have then been applied to developmental disorders in an attempt to elucidate the innate modular structure of the cognitive system. However, such methodology has been severely criticised by the proponents of neuroconstructivist models (Karmiloff-Smith, 1997; 1998). For example, such an approach has been argued to greatly over-simplify the path from gene to behaviour, as no known "area-specific" genes have been identified which might be directly linked to domain-specific developmental outcomes (Karmiloff-Smith & Thomas, 2002). Secondly, the assumption that the behavioural impairments seen in developmental disorders at the end-point of development are the consequence of a deficit in a single module has been questioned, as this would suggest that the rest of the cognitive system would develop normally. Karmiloff-Smith and Thomas (2002) and Bishop (1997) have argued that this is unlikely; firstly, because the modules would have to develop independently of brain development, or alternatively, that the modules would need to have innate domain-specific content. There is evidence to show that both brain localisation and neural specialisation occur gradually over the course of development in areas such as language (Neville, 1991). Thus, the neuroconstructivist approach (Elman et al., 1996; Karmiloff-Smith, 1998) considers developmental disorders on the basis of different developmental trajectories, which result from initial abnormalities at a neurocomputational level, as opposed to damage to larger brain mechanisms. Essentially, development is seen as an interactive process, where interactions with an environment drive the course of cognitive organisation. Importantly, this model is of great relevance to autism, as it "allows" that developmental disorders may be characterised by a pattern of cognitive strengths and weaknesses. Furthermore, it is suggested that comparable behaviours between individuals with developmental disorders and typical development might "mask" distinct underlying cognitive processes. The idea that a capacity is "spared" on the basis of no ostensible deficit at the behavioural level is assumed to be wrong due to the inherently interactive nature of development. This will be considered in more detail below. However, it is noteworthy here that this model highlights further shortcomings in the weak central coherence theory, in that it offers no developmental explanation for the ostensibly "preserved" perceptual abilities. The weak central coherence theory succumbs to the explanations of the adult brain damage model, assuming that "spared" abilities reflect unimpaired cognitive modules. In other words, that the brains of individuals with autism are characterised by a fractionated pattern of impaired and spared modules, present at birth. There is neurological evidence to show, for example, that when solving theory of mind tasks, individuals with autism recruit different neural resources compared to typical individuals (Happé et al., 1996); differences that may be entirely masked at the behavioural level.

According to the neuroconstructivist models, all neural networks are fundamentally seen as learning systems, where a number of initial constraints, present before onset of learning, drive the course of development. Thus, the selective deficits observed in autism would be explained in terms of shifts in these initial constraints. As numerous studies have highlighted atypical social orientation behaviours in children with autism, it seems plausible to suggest that the systems involved in social information processing might be particularly affected. Furthermore, according to this conceptualisation, the relationship between domain-general and domain-specific processes is an interactive one: all processes begin as domain-general, but when combined with the initial constraints and the related shifts in such constraints for specific domains, specialisations emerge as a result of interaction with a learning environment. Thus, in this view, all networks start off with a certain structure but no representational content, and become gradually modularised as a result of learning. Johnson (2000; 2001) has extended the emergence of specialisations in cognitive development to the underlying functional brain development. Of particular interest is the cerebral cortex, associated with higher cognitive and perceptual functions, which shows structural and functional changes during post-natal development (Johnson, 1997). Of central importance is the notion of initial biases in information-processing systems, which result in some cortical pathways being more optimally suited to processing certain types of input. It should be noted here that as all processes begin as domain-general, initially several connected competing pathways are engaged in the processing of a wide range of stimuli. It has been suggested that the cognitive functions that emerge during infancy and childhood are linked to increasing interactions between different brain regions (Johnson, 2001). Secondly, by the process of specialisation, referring to the degree to which a particular cortical area is selective in its response properties (Johnson, 1999), the initial biases are assumed to strengthen. Possible underlying neurocomputational mechanisms include cortical pruning of inappropriate neural connections and inhibition of alternative pathways (Jacobs, 1999). This allows some cortical pathways to become more efficient relative to other alternative and co-active pathways, at processing certain type of stimuli. The changes in brain localisation during development are also seen as a direct consequence of specialisation. This is because by specialisation, fewer pathways become activated by a particular stimulus as most of the initially competing pathways have become fine-tuned to other functions (Johnson, 2000). Returning to the notion of initial biases, Johnson (2001) argues that these lead infants to attend to and process certain stimuli differently and furthermore, that they drive subsequent learning and brain plasticity. In the light of the previously mentioned notions of the enactive mind hypothesis, socially relevant stimuli have been suggested to be more salient than non-social information, due to their survival value (Bates, 1979; Klin et al., 2000). This is considered to be crucial for learning, as the biases ensure that the developing brain pathways receive more input from relevant sources, by guiding the infant's attention to such. In this view, the infant is thought to play an active role in the process of his or her own brain specialisation. With regard to autism, it is well established that several cortical and sub-cortical regions are implicated in the disorder (Filipek, 1999; Minshew, 1996; Piven, Saliba, Bailey, & Arndt, 1997), and that the salience of social stimuli is much reduced (e.g., Dawson et al., 1998). Johnson (2001) argues that aberrant specialisations in autism are the result of the additive effects of initial brain abnormalities, deviant patterns of interaction, and abnormal connectivity between different brain regions. Thus, as in autism, behavioural deficits and abilities emerge after the networks are trained, it would be wrong to assume that the ostensibly "spared" abilities reflect typical brain organisation.

In this introduction, no effort has been made to provide a comprehensive review of all the theories that have been proposed to account for the cognitive, social, and linguistic impairments found in individuals with a diagnosis of autism. Instead, the scope of the literature has been limited to focus on how the enhanced perceptual abilities in the musical domain may relate to the impairments seen in higher-level language functions in autism, particularly from the social-developmental perspective.

In this thesis, the relationship between perceptual abilities and higher-level linguistic processes in autism will be explored, especially in relation to the salience of social cues. The studies to be reported aim to investigate linguistic and musical information processing in children with autism with regard to processing "musical" information in relation to varying degrees of linguistic and pragmatic meaning. The rationale for selecting this topic is two-fold. One concerns the "preserved" pitch processing abilities in the musical domain that have been highlighted for individuals with autism. The second concerns the well-established semantic and pragmatic deficits that are virtually universal in autism. As speech prosody is primarily conveyed by variations in pitch, comparing the processing of analogous pitch information across speech and musical stimuli may elucidate the salience of social information in autism. Further studies will seek to investigate the processing of speech for meaning, together with the understanding of perceptually cued linguistic information (prosody). In chapter two, experiments one and two will test the ability of children with autism and matched controls to process pitch contours in comparable speech, speech-like, and musical stimuli, in relation to their semantic competence. In chapter three, experiment three will directly compare the processing of perceptual versus semantic information in speech, in order to identify any speech processing biases in autism. In chapter four, experiment four will determine how accessible identical pitch sequences are when embedded in uni- and cross-modal speech and music stimuli pairs. In chapter five, a pilot study into rhythmic processing of speech will be presented (experiment five). Chapter six will be concerned with formally assessing the receptive and expressive prosodic abilities of the children with autism and their matched controls, using the PEPS-C test battery (Peppé, McCann, & Gibbon, 2003). In chapter seven, experiment six will test the understanding of the pragmatic-linguistic use of intonation employing stimuli that are representative of naturalistic conversational contexts. Finally, chapter eight will attempt to elucidate the relationship between perceptual processing skills and higher-level speech processing abilities, by comparing the performance of subgroups of children with autism formed on the basis of their semantic competence, in the experiments reported in this thesis.

Chapter Two

Sensitivity to Pitch Contour in Auditory Stimuli in Children with Autism

Summary: In the studies reported in this chapter, children with autism and their age- and verbal intelligence matched controls were tested for their ability to extract four different pitch contours from short intact speech, synthesised speech, and music samples. In experiment two, which incorporated intact speech and music stimuli, control questions were included to assess the extent of the semantic processing of the speech items. Groups of children with high- and low-functioning autism participated in experiment two. Together, the findings showed that children with autism possessed significantly enhanced sensitivity to pitch contour information in all of the stimuli employed in these studies, suggesting a domain-general ability. Furthermore, it was shown that the superior processing of perceptual aspects of speech occurred together with significantly compromised semantic processing. When the data from the high- and low-functioning

children were analysed separately, the pattern of results remained virtually unchanged.

INTRODUCTION

The question to be asked in this chapter concerns how enhanced musical pitch processing in autism (Bonnel, Mottron, Peretz, Trudel, Gallun, & Bonnel, 2003; Heaton, 2003; Heaton, Hermelin, & Pring, 1998; Mottron, Peretz, & Ménard, 2000) might influence such individuals' perception of speech. The hypotheses to be tested in the experiments described in this chapter state that children with autism will show enhanced processing of, and thus greater sensitivity to, "musical" aspects of speech (i.e., pitch contours) compared to their control children, and that they will show reduced processing of speech for meaning. The rationale that gives rise to this hypothesis is based upon the following lines of evidence: (a) as was mentioned above, cognitive research has highlighted enhanced pitch processing abilities in music in individuals with autism (e.g., Heaton, 2003; Heaton et al., 1998; Heaton, Pring, & Hermelin, 1999; Mottron et al., 2000); (b) children with autism show decreased orientation towards verbal and social information compared with non-social stimuli (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Klin, 1991); (c) the tendency to process language for meaning is reduced in autism (Frith & Snowling, 1983; Happé, 1997; Hermelin & O'Connor, 1967; Tager-Flusberg, 1991); and finally, (d) neuropsychological and psychophysiological studies have found evidence of reduced salience of "speechness" quality of sounds in autism, indicating speech-selective attentional and processing deficits at the biological level (Čeponienė, Lepistö, Shestakova, Vanhala, Alku, Näätänen, & Yaguchi, 2003; Gervais, Belin, Boddaert, Leboyer, Coez, Sfaello, Barthélémy, Brunelle, Samson, & Zilbovicius, 2004). Furthermore, research suggests atypical neural-level processing of semantic information in individuals with autism (Dunn, Vaughan Jr., Kreuzer, & Kurtzberg, 1999). To address these issues, the experimental stimuli will consist of three conditions; that of semantically intact speech, semantically impoverished speech, and music, which will share the same pitch and temporal characteristics. Experiment one will compare the processing of pitch in semantically intact speech samples with that in impoverished speech samples. Experiment two will compare the processing of pitch across intact speech and musical domains. It is predicted that children diagnosed with autism will be better able to extract the pitch contours in auditory samples in all experimental conditions compared to their age- and verbal intelligence-matched counterparts. Since auditory attention in autism can be expected to be more weakly directed towards semantic components in speech (e.g., Happé, 1997), it is further predicted that children with autism will perform equally well across all experimental conditions, show increased sensitivity to the pitch properties of speech in comparison to their control children, and show reduced processing of speech for meaning. Furthermore, in the control children, it is anticipated that the typical bias towards semantic processing will interfere with the processing of the perceptual level of speech.

EXPERIMENT ONE: EXPLORING THE SENSITIVITY TO PITCH CONTOUR INFORMATION IN INTACT AND SYNTHESISED SPEECH

Summary: In this study, children with autism and their matched controls were tested for their ability to extract four different pitch contour patterns from short intact speech and impoverished speech samples. For the semantically impoverished condition, the semantically intact sentences were synthesised so that whilst no phonological information was audible, both sets of sentences shared the same pitch contours.

METHOD

Participants

All the children in the autism group were attending a specialist educational establishment for children with autistic spectrum disorders. Each child had received a diagnosis of an autistic spectrum disorder according to standard clinical criteria. Nineteen male and three female children, aged from 8 years, 2 months to 16 years (mean 12 years, 4 months, *SD* 2.28), participated in the study. Their standardised scores on the Peabody Picture Vocabulary Test (PPVT) (Dunn & Dunn, 1981) ranged from 55 to 115 (mean 90, *SD* 17.36). The children in the control group were matched to their autistic counterparts in a pair-wise fashion on the basis of chronological age and their standardised scores on the PPVT. All control children were recruited from mainstream schools, although some of these children were classified as having special educational needs. None of these children had a diagnosis of a psychiatric disorder. This control group included 13 male and nine female children, aged from 7 years, 6 months to 16 years, 7 months (mean 12 years, 3 months, *SD* 2.41). Their standardised scores on the PPVT ranged from 55 to 118 (mean 89, *SD* 15.57).

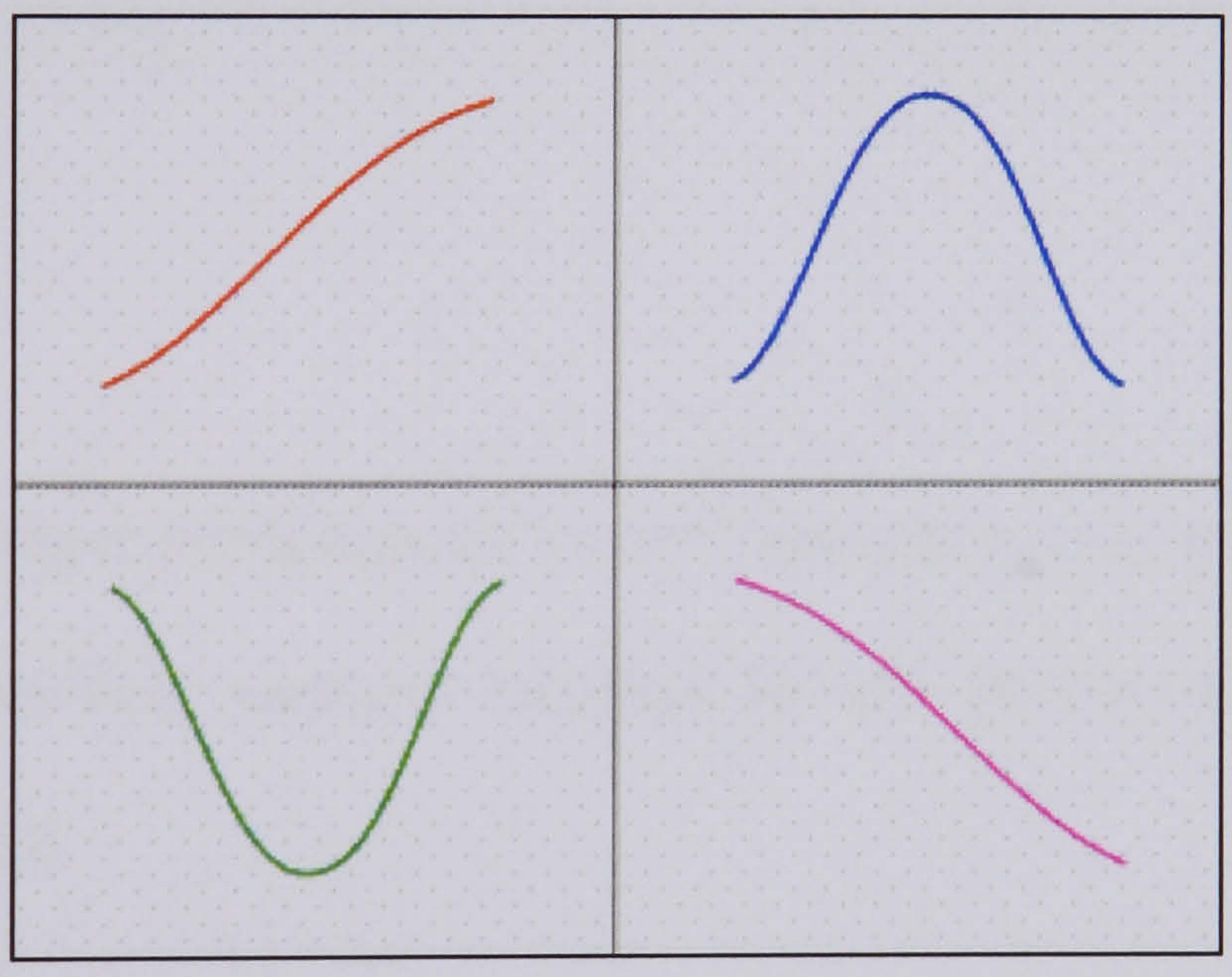
Test stimuli

The experiment included two conditions, that of 16 semantically intact and 16 semantically impoverished (or de-lexicalised) speech samples. Each stimulus conformed to one of four distinct pitch contours (rising, falling, U-shape and inverted U-shape), shown Figure 2.1 below. The presentation of the 32 speech samples was randomised in respect to the ordering of the different pitch contours and stimulus class.

Semantically intact stimuli: Each sentence was uttered in such a way as to produce one of four pitch contours: ascending, descending, low-high-low, and high-low-high. Fundamental frequency was then extracted every 10 milliseconds using the Praat speech editor (Boersma, 2001). Visual inspection of the fundamental frequency (F_0) curves was used to ensure that the contours were produced as intended; when needed, sentences were re-recorded until the desired contours were obtained. The sentences were constructed in such a way that each was five syllables in length, and we attempted to select verbs, nouns, and adjectives that occur frequently in spoken language. Examples of sentences included “What a nice red hat”, “Reading books is fun”, and “Tom loves eating chips”. The sentences were uttered by a native English speaking female.

Semantically impoverished stimuli: For the de-lexicalised versions, F_0 curves were used to synthesise a "hummed" sentence with exactly the same fundamental frequency variations as in the original sentence. The "hum" sound is a continuous schwa vowel synthesised with five formants (as provided in Praat) and varying only in F_0. During unvoiced portions of the original sentence, the hum is interrupted by a silence of equal duration. This de-lexicalisation method is a standard way to exclusively preserve the melodic information of a sentence (e.g., Ramus & Mehler, 1999). The stimuli were presented on a laptop computer by the experimenter, and each auditory sample was followed by a visual display depicting the four musical contours, shown in Figure 2.1 below.

Figure 2.1 Graphic representation of the four different pitch contours



Procedure

The children were tested individually in a quiet room in their own school. A training phase preceded the experimental testing, in which the visual representation of the four musical contours was shown on the laptop computer screen in front of the child. The experimenter explained that sentences could be said in different ways so that they form differently sounding “shapes”, depending on the “height” of the voice. A sentence, similar in properties to those to be used in the experiment, was read by the experimenter in all four of the contour shapes to be tested. Whilst speaking, the experimenter simultaneously followed the matching graphic contour representation on the visual display with her finger. A different sentence was then used, and the child was asked to point to the visual shape that corresponded to the auditory signal. If the child’s response was inaccurate, the experimenter corrected the child. Once the child was familiar with the procedure and had made at least two correct responses, the experimenter told the child that she had more similar sentences recorded on the computer. The child was also told that some of the voices that s/he was going to hear were going to be just “noise”, but that this “noise” depicted exactly the same “shapes” as the sentences they had already heard. In the testing phase the child was not given any feedback by the experimenter. The child set the testing pace although quick responses were encouraged.

RESULTS

The means and standard deviations for correct identification of semantically intact and semantically impoverished sentence contours for the autism and control groups are displayed in Table 2.1.

Table 2.1 Means and standard deviations for the correct identification of sentence contours for both the children with autism and their controls

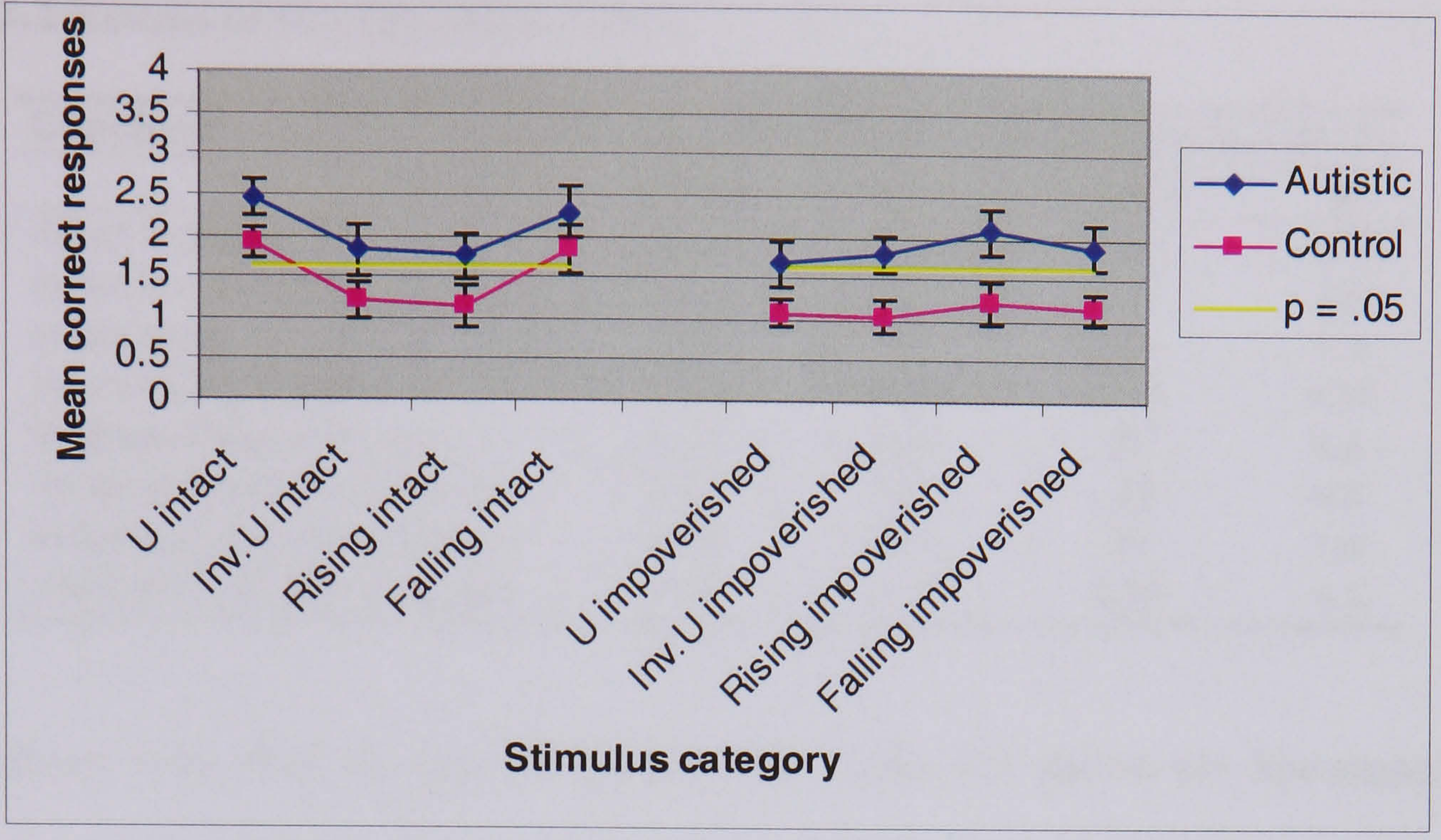
	Semantically intact condition		Semantically impoverished condition	
	Mean	**SD**	**Mean**	**SD**
Autism group (N=22)	8.86	3.59	7.36	3.30
VIQ- and age-matched controls (N=22)	6.27	3.30	4.27	2.05

*Maximum score per condition = 16

A two-way analysis of variance with condition (intact/impoverished) as the within-group factor and diagnosis (autism/control) as the between-group factor, was carried out on the data. The analysis revealed a highly significant effect of diagnosis (F (1, 42) = 12.31, p = .001), with the children with autism performing at a higher level to those in the matched control group, and a significant effect of condition (F (1, 42) = 21.64, p < .001), with better overall performance occurring in the semantically intact condition. The condition by group interaction was not significant (F (1, 42) = .44, n.s.).

In order to explore the data more fully, patterns of performance across the eight individual stimulus categories were plotted for both experimental groups. Individual mean scores with error bars for both groups are shown in Figure 2.2 below. The yellow lines denote chance level performance.

Figure 2.2 Mean number of pitch contours classified correctly



*Maximum score per condition = 4; chance level: *p* = .05;
error bars represent ±1 standard error

Figure 2.2 shows that the pattern of performance was very similar across the two groups. This will be considered further in the general discussion. However, the significant main effects of stimulus and group, together with Figure 2.2, illustrate that there were large differences in performance between the children with autism and their control children. Since the range of mean total scores of the two stimulus conditions was very wide, mean group scores for the individual semantically intact and semantically impoverished stimulus categories were compared with chance level performance (1) using one-sample t-tests. This analysis revealed that, for the autism group, performance was significantly above chance for all stimuli, whilst the control children performed at chance level in all semantically impoverished stimulus categories, only showing above-chance level performance in the intact U-shape and in the intact falling shape. This will be discussed further. The t-values (21) and their corresponding *p*-values are shown in Table 2.2 below.

Table 2.2 Results of the one-sample t-tests

Condition	Autism group (N=22)		Control group (N=22)	
	t-value	**p**	**t-value**	**p**
Intact U-shape	6.20	<.001	4.92	<.001
Intact inv. U-shape	3.24	<.01	1.5	n.s.
Intact rising shape	3.16	<.01	.35	n.s.
Intact falling shape	4.60	<.001	3.13	<.01
Impoverished U-shape	2.14	<.05	.27	n.s.
Impoverished inv. U-shape	3.91	.001	-.22	n.s.
Impoverished rising shape	3.69	.001	.19	n.s.
Impoverished falling shape	3.70	.001	1.23	n.s.

Correlations were then carried out on the data. Table 2.3 shows the Spearman's rho values for the children with autism (and control children in parentheses) between the variables. The results indicate a high correlation between the two experimental conditions for both groups, suggesting a general ability to process pitch contour information in vocal stimuli. All other correlations failed to reach significance.

Table 2.3 Relationship between verbal intelligence, age, and experimental data for the children with autism (control children in parentheses)

	Semantically intact	Semantically impoverished	Age
VIQ	.145 (-.062)	.275 (-.064)	.304 (.216)
Semantically intact		.703** (.545**)	.184 (.369)
Semantically impoverished			.045 (.245)

** *p* .01

Thus, in summary, the findings from this experiment supported the experimental hypothesis that children with autism show an enhanced sensitivity towards pitch information in speech-like stimuli. These findings, together with those obtained from experiment two, will be discussed further later in this chapter.

EXPERIMENT TWO: THE SENSITIVITY TO PITCH CONTOUR INFORMATION IN SPEECH AND MUSIC: A PARTIAL REPLICATION

INTRODUCTION

The aim of experiment one was to investigate the extent to which enhanced musical pitch analysis skills in autism might generalise to vocal stimuli. When children were presented with intact and synthesised speech samples which shared the same musical contours, pitch information was found to be significantly more salient for the children with autism than for matched controls. However, the data failed to support the hypothesis that semantic content would disrupt the processing of pitch in speech in the control children, since both groups exhibited enhanced ability to extract the melodic contours from the semantically intact speech stimuli. Thus, as experiment one failed to elucidate the role of semantic information in vocal stimuli in relation to perceptual processing, experiment two was carried out with two paradigm modifications. Firstly, the semantically impoverished condition was substituted with analogous five-tone musically produced contours, each depicting one of the four pitch contours. The rationale was to introduce auditory stimuli belonging to a different domain to that of vocal information, the processing of which would be expected to rely upon different neural mechanisms to that of speech. It was hoped that by comparing the processing of pitch in analogous speech and musical stimuli, the role of semantic content in speech would be highlighted. A further rationale for this experiment was to replicate the earlier observed effect indicating enhanced sensitivity to pitch information in speech in autism, and to extend it to specifically musical information. The second modification concerned a semantic processing measure comprising of control questions based upon the information given in the intact speech sentences. Thus, the processing of speech for meaning was assessed, in order to examine the relationship between the children's processing of perceptual and semantic information in speech.

Groups of high- and low-functioning children with autism participated in the study. The first analyses were carried out on the mixed data including the results from both the high- and low-functioning children, and further analyses were performed on separate data from the high- and low-functioning children with autism. Psychological studies traditionally divide high- and low-functioning children with autism on the basis of full scale IQ scores above and below 70, and the same method was employed in this study. The rationale for including a low-functioning group was to investigate whether the observed effect of experiment one can be seen in children with autism from all levels of intellectual functioning; more specifically, whether pitch processing abilities might be robust against intellectual impairment. Evidence for preserved pitch processing abilities in the presence of intellectual impairment was found in a study carried out by McLeish & Higgs (1982). Here, the musical aptitudes of 121 children with intellectual impairment were assessed using the Bentley (Bentley, 1966) and Seashore (Seashore, 1957) musical test batteries. The findings showed that pitch discrimination was not significantly different in such children when compared with that of typically developing children matched for chronological age. Further evidence has been reported in studies with children with Williams syndrome (e.g., Don, Schellenberg, & Rourke, 1999; Lenhoff, 1996). This is a developmental disorder of genetic origin, characterised by intellectual impairment and an uneven cognitive profile such that language and meta-representational abilities appear relatively spared, but severe deficits are observed in visual-spatial domains (Bellugi, Wang, & Jernigan, 1994). The children with low-functioning autism require intellectually impaired controls, who were recruited from schools catering for children with moderate learning difficulties. Only children with a learning difficulties condition of unknown origin were included, so as to rule out any influences of an accompanying disorder.

The hypothesis for the following experiment states that children with autism will perform at a higher level in pitch contour recognition across music and language domains, than age- and intelligence matched controls. It is further expected that the children with autism will show reduced semantic processing of speech compared to their controls. This effect is expected to be more striking in the sample consisting of children with low-functioning autism, as, in such individuals, autism is accompanied by intellectual impairment. This form of autism is typically associated by virtual absence of language acquisition or mutism (Minshew, Goldstein, & Siegel, 1995). Approximately half of the autistic population fails to acquire functional language during their life-time (Bailey, Phillips, & Rutter, 1996), and there is evidence to suggest that deficits in speech comprehension in autism are relatively more severe than those observed in production (Lord, 1985; Lord & Paul, 1997). One study by Miranda-Linné and Melin (1997) compared the language abilities of mute and verbal individuals with autism using the Autism Behaviour Checklist (Krug, Arick, & Almond, 1980). The findings showed that the mute individuals were significantly poorer in the comprehension of speech, in comparison to those with language. Furthermore, the mute individuals also presented a more severe autistic symptomatology. It is thus plausible to hypothesise that individuals with low-functioning autism will show more marked impairments in semantic processing than those with the high-functioning form of the disorder.

Further psychometric data from children with autism and their matched controls was obtained. More specifically, the children's non-verbal cognitive ability was assessed with the Raven's Standard Progressive Matrices (Raven, Court, & Raven, 1992), and children with autism were matched to their controls on this parameter in addition to age and verbal intelligence. The rationale for matching groups on the Raven's Matrices was to control for the possible contribution of non-verbal intelligence to the ability to process pitch information. The Raven's Matrices is assumed to reflect the general "g" aspect of intelligence, which is independent of crystallised intelligence (Frith, 2003). Evidence has shown that full-scale intelligence score correlates strongly with musical ability in intellectual impairment (e.g., McLeish & Higgs, 1982).

METHOD

Participants

Sample one: whole group – mixed ability: Twenty-two male and three female children with a formal diagnosis of an autistic spectrum disorder participated in the experiment. These children were different from those who participated in experiment one, and several of these children participated in the experiments presented in the remainder of this thesis (see appendix one for a table showing participation in the various experiments). These children were recruited from two specialist educational establishments for children with autism. These children's ages ranged from 7 years, 8 months to 16 years, 9 months (mean 12 years, 5 months, *SD* 2.35), their standardised scores on the British Picture Vocabulary Scale (BPVS) (Dunn, Whetton, & Pintilie, 1997) varied from 40 to 135 (mean 77, *SD* 23.85), and their raw scores varied from 31 to 142 (mean age equivalent 8 years, *SD* 27.85). Their standardised scores on the Raven's Progressive Matrices (RPM) (Raven et al., 1992) ranged from 66 to 119 (mean

89, *SD* 14.08, mean MA 11 years, 6 months). Nineteen male and six female control children were recruited from three different schools: a mainstream primary school (10 children), a primary school for children with moderate learning difficulties (seven children), and a mainstream secondary school with a specialist unit for children with learning difficulties (eight children). The control children were matched to the children with autism on the basis of age and their standardised score on the BPVS and RPM. The children with learning difficulties did not have a diagnosis of any clinical disorder. These children were aged from 7 years, 6 months to 16 years, 3 months (mean 11 years, 10 months, *SD* 2.55), their standardised scores on the BPVS ranged from 40 to 124 (mean 80, *SD* 20.98), and their raw scores ranged from 34 to 129 (mean age equivalent 8 years, 2 months, *SD* 21.75). The standardised scores on the Raven's Matrices for these children ranged from 61 to 110 (mean 83, *SD* 15.83, mean MA 9 years, 10 months).

Sample two: high-functioning autism subgroup

Thirteen male and three female children with high-functioning autism were identified from the sample described above. These children were aged from 7 years, 8 months to 16 years, 9 months (mean 12 years, 2 months, *SD* 2.65). These children's standardised BPVS scores varied from 70 to 135 (mean 91, *SD* 16.02), and their raw scores ranged from 56 to 142 (mean age equivalent 9 years, 10 months, *SD* 23.50). Their standardised scores on the Raven's Progressive Matrices ranged from 69 to 119 (mean 94, *SD* 13.73, mean MA 11 years, 5 months). Twelve male and four female control children were identified. These children were aged from 7 years, 6 months to 16 years, 3 months (mean 11 years, 0 months, *SD* 2.34), their standardised BPVS scores ranged from 70 to 124 (mean 94, *SD* 14.52) and their raw scores ranged from 58 to 129 (mean age equivalent 9 years, 7 months, *SD* 19.20). Their standardised scores on the Raven's Progressive Matrices varied from 72 to 110 (mean 91, *SD* 12.92, mean MA 10 years).

Sample three: low-functioning autism subgroup

Nine male children with low-functioning autism were identified from sample one described above. These children were aged from 10 years, 2 months to 16 years, 6 months (mean 12 years, 10 months, *SD* 1.76). These children's standardised BPVS scores ranged from 40 to 68 (mean 52, *SD* 11.51), and their raw scores ranged from 31 to 84 (mean age equivalent 5 years, 8 months, *SD* 15.65). Their standardised scores on the Raven's Progressive Matrices varied from 66 to 88 (mean 77, *SD* 9.31, mean MA 9 years, 11 months). Eight male children and one female control child with moderate learning difficulties were identified. The children were aged from 10 years, 1 month to 15 years, 9 months (mean 13 years, 6 months, *SD* 2.01), their standardised BPVS scores ranged from 40 to 67 (mean 58, *SD* 9.61), and their raw scores ranged from 34 to 93 (mean age equivalent 6 years, 1 month, *SD* 19.05). Their standardised scores on the Raven's Progressive Matrices varied from 62 to 86 (mean 70, *SD* 8.46, mean MA 9 years, 5 months).

Test stimuli

The paradigm used was virtually identical to that employed in experiment one, but here the experimental conditions included 16 speech and 16 analogous music stimuli. The order of presentation of the 32 stimuli was randomised with respect to the ordering of the different pitch contours and stimulus class. The stimuli were presented on a laptop computer, and each auditory sample was followed by a visual display representing the four pitch contours, shown in Figure 2.1. However, in the current experiment, each of the graphically expressed contours was assigned a colour that was consistently associated with the shape throughout the experiment, to enhance association and to make the experiment more visually attractive for the children. The colours were as follows: the rising shape was red, the falling shape was purple, the U-shape was green, and the inverted U-shape was coloured blue.

Speech condition: The stimuli were taken directly from experiment one (see experiment one for more details), and consisted of 16 unsynthesised five-syllable sentences read by a female voice, as previously described. Each sentence conformed to one of the four pitch contours shown in Figure 2.1, so that four sentences corresponded to each contour shape.

Music condition: Sixteen five-tone melodies, analogous perceptually to the speech samples, were generated with a Casiotone 202 electronic keyboard (acoustic piano setting). Each musical melody corresponded to one of the four pitch contours shown in Figure 2.1. The melodies were matched for duration to the stimuli in the speech condition.

Semantic processing measure: Sixteen control questions, based on the semantic information given in each of the sentences in the speech condition, were generated. The semantic questions did not directly name any of the words (with the exception of names) incorporated into the speech stimuli, to prevent ceiling level performance from occurring in the control group. For example, for the sentence (1) "I like eggs and ham", the control question was, "what is the lady's favourite breakfast?", for the sentence (2) "Tom loves eating chips", the control question was, "What is Tom's favourite food?", and for the sentence, (3) "What a nice red hat", the control question was, "What keeps the ears warm?". For sentence one, the answers "eggs and ham", and either "eggs" or "ham" scored one point, and answers such as "omelette" or "bacon" scored half a point. Answers such as "cereal" and "pastries" scored zero points. For sentence two, the answers "chips" and "potato chips" scored one point, and the answer "potatoes" scored half a point. Any response referring to non-potato-based food scored zero points. For sentence three, only the answer "hat" scored one point, and answers such as "cap" and "ear-muffs" scored half a point. Each correct answer thus scored one point, making the maximum score for this condition 16.

Procedure

The children were tested individually in a quiet room in their own school. A training phase preceded the experimental testing. The child was told that s/he was going to hear some short spoken sentences and short melodies played on a piano from the computer. Two training blocks of four sentences were given, one corresponding to the speech condition, and one to the music condition, and the order of these blocks was counterbalanced across participants. In the speech condition training, the child was told that sentences could be said in different ways so as to form differently sounding shapes, depending on how "high" or "low" the voice sounds. The child was then shown the visual display on the laptop computer, and told that his or her task would be to point to the shape that s/he thought best matched each sound. A training block of four sentences, similar to those used in the actual experiment, was then played on the computer. If the child's response was inaccurate, the experimenter corrected the child. The child was further told that each of the sentences told a little story, and now the experimenter was going to play the sentences again, but this time she would ask a simple question relating to the information that was given in the sentence. In order to move to the second block of training, the child was required to have made at least two correct judgements in response to the contour information. If not, then the same block of sentences was played again, until this criterion had been reached. With regard to the semantic control questions, no such criterion was set due to the well-known semantic processing impairments in autism. Moreover, some of the children with low-functioning autism who participated in the experiment were virtually mute. For the music condition training, the experimenter explained to the child that musical melodies could form the same shapes as could the sentences. The training block consisting of four different melodies was then played on the computer, and the child was told to match each of the melodies to the visual display of the pitch contours. The experimenter again corrected the child until s/he had made two accurate responses. Following the successful completion of the two training blocks, the experimenter told the child that she had more similar sentences and melodies recorded onto the computer. In the actual testing, no feedback was given. With regard to the administration of the semantic control questions, following the child's perceptual judgement in response to each of the intact speech stimuli, the experimenter played the sentence again, and asked the control question.

RESULTS FOR SAMPLE ONE: ANALYSIS OF DATA FROM A MIXED SAMPLE OF HIGH- AND LOW-FUNCTIONING CHILDREN WITH AUTISM

The means and standard deviations for correct identification of speech and musical contours are displayed in Table 2.4.

Table 2.4 Means and standard deviations for the correct identification of pitch contours for both the children with autism and their matched controls

	Speech condition		Music condition	
	Mean	**SD**	**Mean**	**SD**
Autism group (N=25)	9.08	2.72	9.24	3.47
VIQ-, NVIQ-, and age-matched controls (N=25)	5.52	2.24	5.48	1.92

*Maximum score per condition = 16

A two-way repeated measures analysis of variance with stimulus class (speech/music) as the within-participants factor, and diagnosis (autistic/control) as the between-participants factor, was carried out on the data. This analysis revealed a highly significant main effect of diagnosis (*F* (1, 48) = 28.77, $p < .001$), with the children with autism showing significantly higher levels of performance overall compared to the control children. Both the main effect of stimulus class (*F* (1, 48) = .04, n.s.) and stimulus class by diagnosis interaction (*F* (1, 48) = .10, n.s.) failed to reach significance. The effects of diagnosis by stimulus class interaction and that of stimulus class failed to reach significance for the reason that, within both groups of children, performance was near equal in both stimulus conditions.

The performance of the two groups of children in the speech and music conditions was compared against chance level performance (4) by applying one-sample t-tests. This analysis revealed that for the children with autism, performance was above chance in the speech (*t* (24) = 9.33, $p < .001$) and music (*t* (24) = 7.56, $p < .001$) conditions. A similar pattern emerged for the control children, in that they showed above chance level performance in both the speech (*t* (24) = 3.40, $p < .005$) and music (*t* (24) = 3.86, $p = .001$) stimulus classes. Thus, these results indicated that both groups of children performed at above chance in the pitch contour task. Furthermore, together with the findings from experiment one, the results indicated that there was no evidence of cross-modal matching (auditory to visual stimuli) difficulties in children with autism: both groups of children with autism (experiment one plus experiment two) showed levels of performance that were significantly above chance level in all three stimulus conditions.

As the experimental hypothesis specifically predicted that children with autism would show reduced processing of speech for meaning, an independent samples t-test was run on the semantic control question data. The means and standard deviations for the semantic control question data for the children with autism and their matched control children are displayed in Table 2.5 below.

Table 2.5 Means and standard deviations for the semantic processing score for both the children with autism and their matched controls

	Semantic processing score	
	Mean	**SD**
Autism group (N=25)	6.28	6.44
VIQ-, NVIQ-, and age-matched controls (N=25)	14.76	1.69

*Maximum score per condition = 16

The analysis described above showed that the control children were significantly better at extracting the meaning of the sentences, as compared to the children with autism (*t* (48) = -6.37, $p < .001$). However, the standard deviation is very large for the children with autism (6.44 versus 1.69 for control children) and their scores ranged from the minimum of zero to the maximum of 16, whereas the range of scores for the children in the control group was from 10 to 16. This will be discussed further.

In order to examine whether overall performance in the pitch contour task might improve with age and intelligence, correlations were carried out between experimental, psychometric, and age data. For the children with autism, good performance in the speech condition correlated positively with performance in the music condition ($r = .80$, $p < .001$), and semantic processing ability was associated with higher levels of verbal intelligence ($r = .69$, $p < .001$). No other significant correlations were found for the children with autism. For the children in the control group, a significant positive correlation emerged between the semantic processing score and the level of verbal ability ($r = .61$, $p = .001$); between the semantic processing score and the level of non-verbal ability ($r = .44$, $p < .05$); and between the levels of verbal and non-verbal intelligence ($r = .71$, $p < .001$). Any other correlations for the children in the control group failed to reach significance. These results will be discussed further.

RESULTS FOR SAMPLE TWO: ANALYSIS OF DATA FROM THE HIGH-FUNCTIONING SUBGROUP

Sixty-four per cent of the children in sample one had intelligence levels within the normal range. The means and standard deviations for correct identification of speech and musical contours for the high-functioning subgroup and their matched controls are displayed in Table 2.6.

Table 2.6 Means and standard deviations for the correct identification of pitch contours for both the high-functioning subgroup and their matched controls

	Speech condition		Music condition	
	Mean	**SD**	**Mean**	**SD**
Autism group (N=16)	9.56	2.80	10.06	3.71
VIQ-, NVIQ-, and age-matched controls (N=16)	5.87	2.58	6.06	2.49

*Maximum score per condition = 16

A two-way repeated measures analysis of variance with stimulus class (speech/music) as the within-participants factor, and diagnosis (autistic/control) as the between-participants factor, was performed on the data. This analysis revealed a highly significant main effect of diagnosis (*F* (1, 30) = 15.85, $p < .001$), with the children with autism showing significantly higher levels of performance overall compared to the control children. Both the main effect of stimulus class (*F* (1, 30) = .81, n.s.) and stimulus class by diagnosis interaction (*F* (1, 30) = .17, n.s.) failed to reach significance.

The children's performance was then compared against chance level (4) by applying one-sample t-tests. For children with autism, performance was significantly above chance level in the speech (*t* (15) = 7.94, $p < .001$) and music (*t* (15) = 6.53, $p < .001$) conditions. The control children also showed above chance level performance with the speech (*t* (15) = 2.91, $p < .02$) and music (*t* (15) = 3.31, $p = .005$) stimuli. Thus, no evidence of cross-modal matching difficulties was found for either group of children.

Performance with regard to the ability to process speech items for meaning was compared between the children with autism and their matched controls. The means and standard deviations for the semantic control question data for the high-functioning subgroup and their matched control children are displayed in Table 2.7 below.

Table 2.7 Means and standard deviations for the semantic processing score for both the high-functioning subgroup and their matched controls

	Semantic processing score	
	Mean	**SD**
Autism group (N=16)	9.00	5.87
VIQ-, NVIQ-, and age-matched controls (N=16)	15.44	0.81

*Maximum score per condition = 16

An independent samples t-test revealed that the control children were significantly better at extracting the meaning of the sentences used in the speech condition, compared with the children with autism (t (30) = -4.35, $p < .001$). However, the standard deviations remained very large for the intellectually able children with autism (5.87 versus .81 for the control children) and their scores again ranged from the minimum of zero to the maximum of 16, whilst the range of scores for the children in the control group was from 13 to 16. This will be discussed further.

In order to examine whether overall performance in the pitch contour task might improve with age and intelligence, correlations were then carried out between experimental, psychometric, and age data. For the children with autism, a significant positive correlation emerged between performance levels in the speech and music conditions ($r = .80, p < .001$) and between the semantic processing score and the level of non-verbal intelligence ($r = .76, p < .005$). Any other correlations for the children with autism failed to reach significance. For the children in the control group, a significant positive correlation emerged between the semantic processing score and the level of verbal ability ($r = .56, p = .025$). No other significant correlations were evident for the control children. It is intriguing to note that for the intellectually able children with autism, semantic processing ability was specifically associated with their level of general, non-verbal, rather than verbal intelligence. This finding is at odds with that obtained for the whole autism sample, suggesting qualitative differences in semantic processing between intellectually able and less able children. This finding will be discussed further.

RESULTS FOR SAMPLE THREE: ANALYSIS OF DATA FROM THE LOW-FUNCTIONING SUBGROUP

As 36 per cent of the children in sample one either had low-functioning autism or moderate learning difficulties, it was of interest to specifically examine levels of performance of children with lower intellectual ability. The means and standard deviations for correct identification of speech and musical contours for the low-functioning subgroup and control children with moderate learning difficulties are displayed in Table 2.8.

Table 2.8 Means and standard deviations for the correct identification of pitch contours for both the low-functioning subgroup and their matched controls

	Speech condition		Music condition	
	Mean	**SD**	**Mean**	**SD**
Autism group (N=9)	8.22	2.49	7.78	2.54
VIQ-, NVIQ-, and age-matched controls (N=9)	5.00	1.87	4.78	1.39

*Maximum score per condition = 16

A two-way repeated measures analysis of variance with stimulus class (speech/music) as the within-participants factor, and diagnosis (autistic/control) as the between-participants factor, was carried out on the data. This analysis revealed a highly significant main effect of diagnosis (*F* (1, 16) = 13.43, $p < .005$), with the children with autism showing significantly higher levels of performance overall compared to the control children. Both the main effect of stimulus class (*F* (1, 16) = .39, n.s.) and stimulus class by diagnosis interaction (*F* (1, 16) = .84, n.s.) failed to reach significance.

The children's performance in the speech and music conditions was then compared against chance level (4) using one-sample t-tests. This analysis revealed that the children with autism showed above chance level performance in the speech (*t* (8) = 5.09, $p = .001$) and music (*t* (8) = 4.46, $p < .005$) conditions. By contrast, the control children's performance was at chance with both the speech (*t* (8) = 1.60, n.s.) and music (*t* (8) = 1.67, n.s.) stimuli. Thus, whilst these findings confirmed that no cross-modal matching impairment was evident in this task in the children with autism of all levels of functioning, the children with moderate learning difficulties performed at chance with all stimuli. This finding will be discussed further.

The ability to process speech items for meaning was compared between the children with autism and their matched controls. The means and standard deviations for the semantic control question data for the low-functioning subgroup and their matched control children are displayed in Table 2.9 below.

Table 2.9 Means and standard deviations for the semantic processing score for both the low-functioning subgroup and their matched controls

	Semantic processing score	
	Mean	**SD**
Autism group (N=9)	1.44	4.33
VIQ-, NVIQ-, and age-matched controls (N=9)	13.56	2.19

*Maximum score per condition = 16

An independent samples t-test revealed that the control children were significantly better at deriving the meaning of the speech items compared to the children with autism (t (30) = -4.35, $p < .001$). An inspection of the standard deviations showed that this value remained large for the low-functioning children with autism (4.33 versus 2.19 for the control children). For the children with autism, scores ranged from zero to 13, whilst the children with moderate learning difficulties achieved scores from 10 to 16.

In order to examine whether overall performance in the pitch contour task might improve with age and intelligence, correlations were then carried out between experimental, psychometric, and age data. For the children with autism, a significant positive correlation emerged between performance levels in the speech and music conditions ($r = .74, p < .03$). Any other correlations for the children with autism failed to reach significance. For the children in the control group, all correlations failed to reach significance.

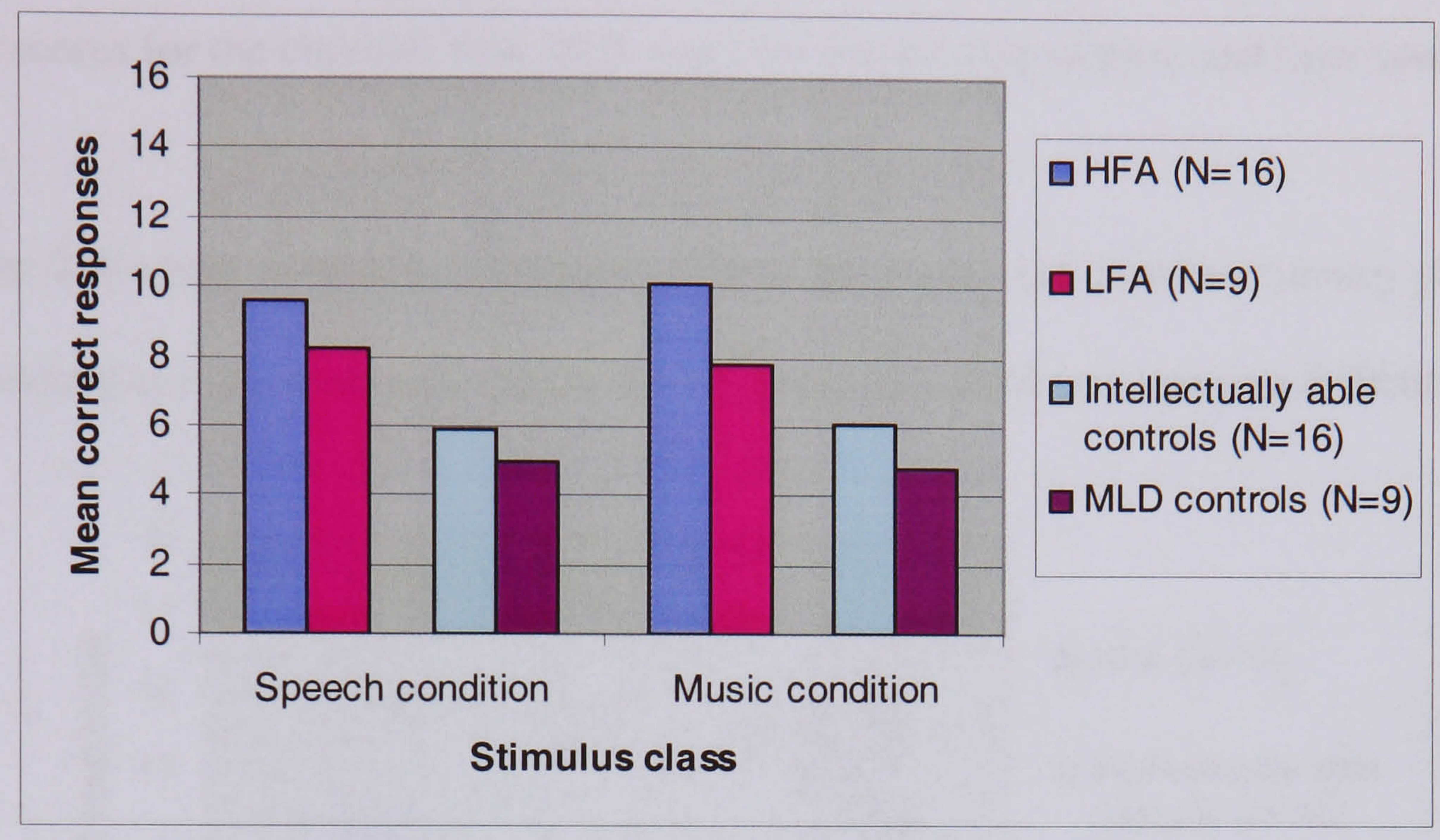
COMPARISON OF DATA FROM THE HIGH- AND LOW-FUNCTIONING CHILDREN WITH AUTISM

Earlier in this chapter, specific hypotheses were made about the ability to process speech at the semantic level by children with high- and low-functioning autism. Furthermore, as very little is known about the ability to process pitch by individuals with intellectual impairment, the data from such children were separated from those obtained from children with high-functioning autism, and analysed separately. The following section will compare levels of performance of children with high- versus low-functioning autism, and their intellectually able controls versus those with learning difficulties, in the pitch contour task and the semantic processing measure.

RESULTS

The group means for the speech and music conditions for the children with high- and low-functioning autism (HFA and LFA respectively) and their controls are shown in Figure 2.3.

Figure 2.3 Means for the correct identification of pitch contours in speech and music stimuli for children with high- versus low-functioning autism and able controls versus controls with moderate learning difficulties

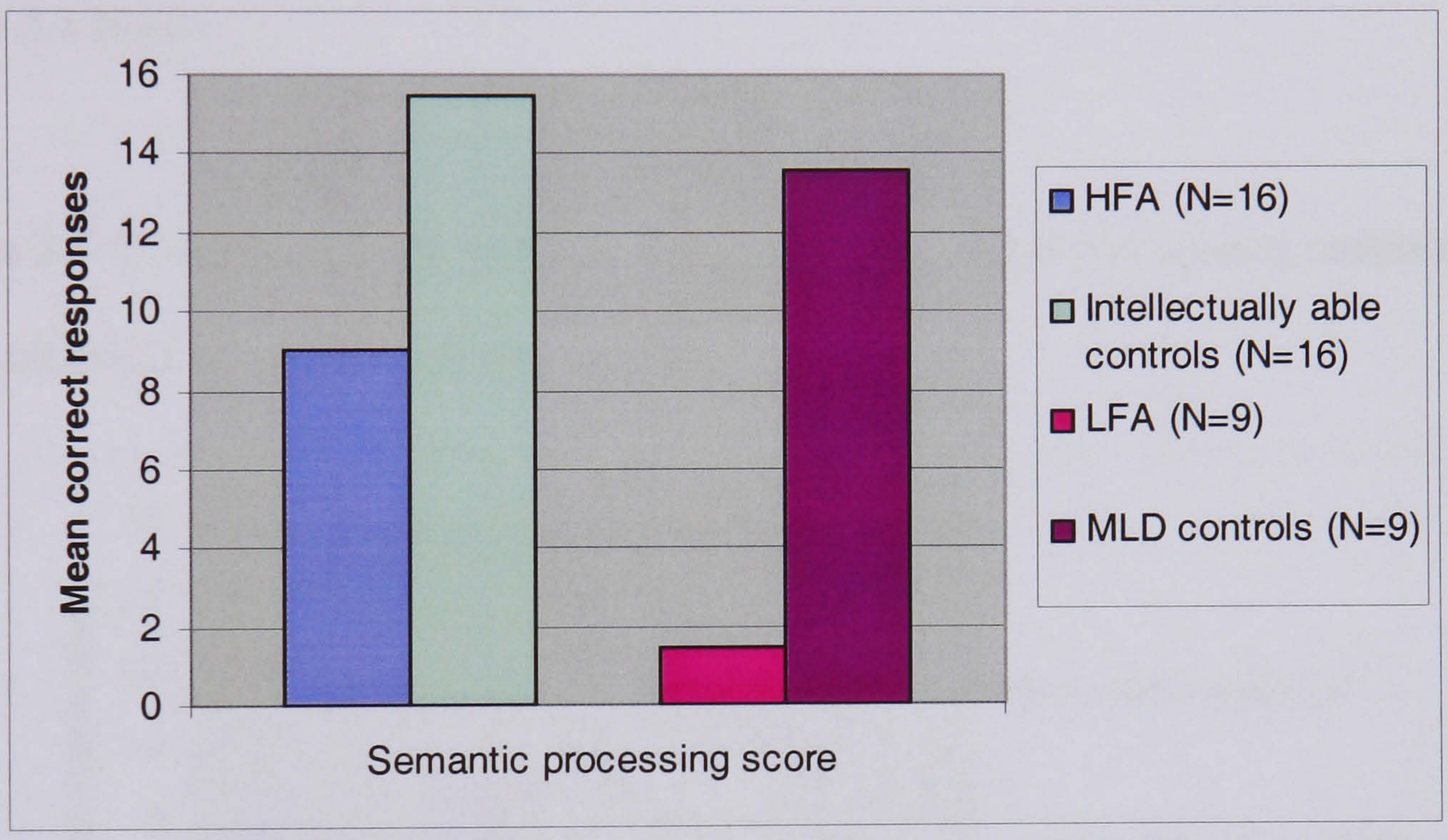


*Maximum score per condition = 16

Independent samples t-tests were performed on the data. For the children with autism, there were no significant differences in performance between the children with the high- and low-functioning form of the disorder, in either the speech (*t* (23) = 1.19, n.s.) or the music (*t* (23) = 1.64, n.s.) condition. Thus, these results reinforce the conclusions that task performance did not rely upon levels of intellectual functioning. An identical pattern of results was obtained for the control children; namely, intellectually able children showed levels of performance that were not significantly higher than those of the children with moderate learning difficulties, with both the speech (*t* (23) = .89, n.s.) and music (*t* (23) = 1.42, n.s.) stimuli. So, these results suggest that pitch processing abilities are robust against intellectual impairment.

As it was specifically predicted that children with low-functioning autism would show more severe semantic processing deficits than those with a high-functioning form of the disorder, the semantic control question data were then analysed. Figure 2.4 shows the mean scores for the children with high- and low-functioning autism, and their controls.

Figure 2.4 Mean semantic processing scores for high- and low-functioning children with autism and controls with typical development and moderate learning difficulties



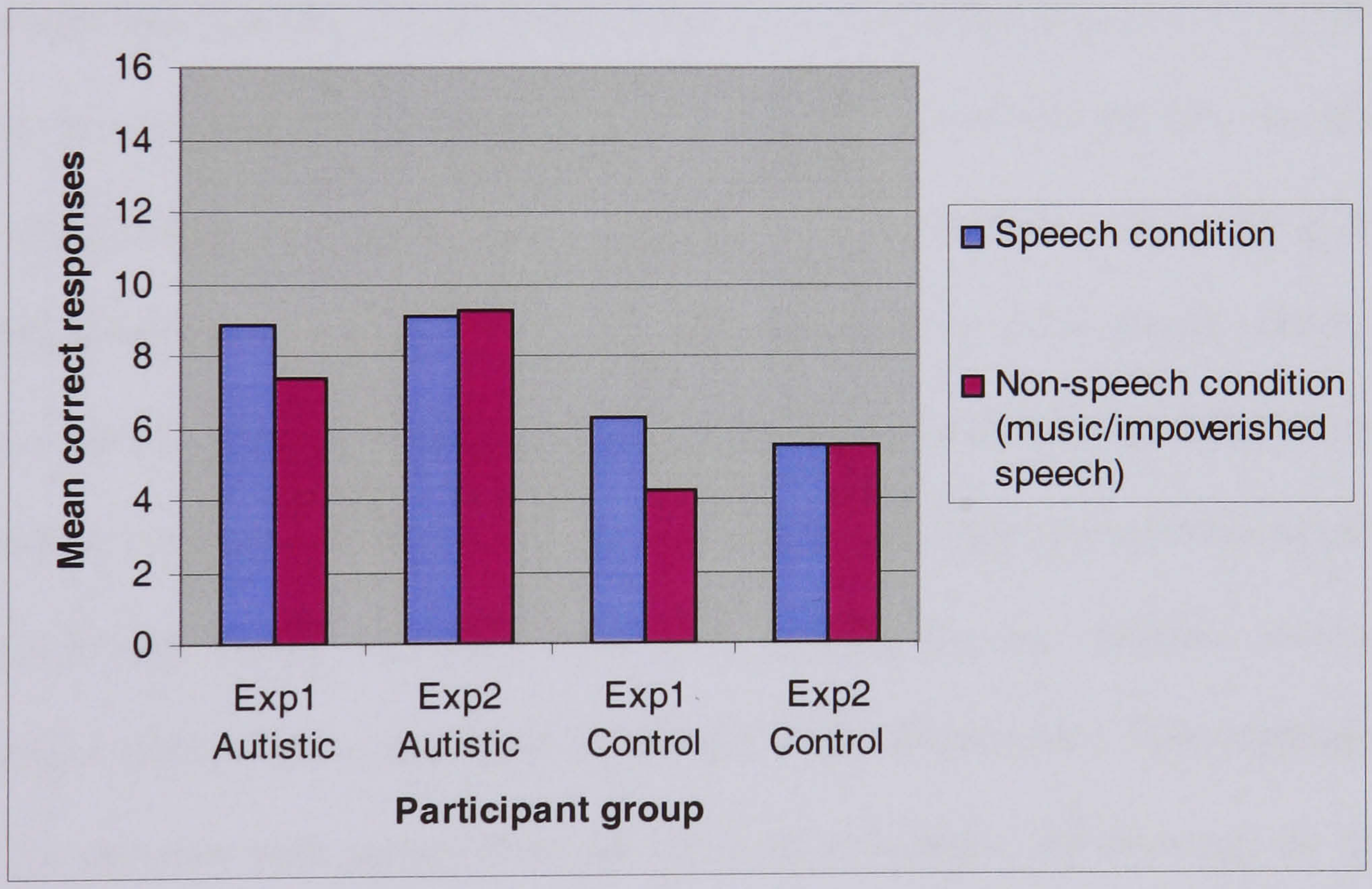
*Maximum score per condition = 16

The results from an independent samples t-test supported the prediction that children with high-functioning autism would be better able to process speech for meaning in comparison to children with low-functioning autism (t (23) = 3.37, $p < .005$). Furthermore, this analysis revealed that the intellectually able control children were more proficient at semantic processing than the children with moderate learning difficulties (t (23) = 3.12, $p = .005$).

COMPARISON OF DATA FROM EXPERIMENT ONE AND EXPERIMENT TWO

Finally, as both of the experiments described in this chapter employed the same paradigm and shared the intact speech condition but used different samples of children, it was of interest to explore patterns of responding across the two experiments. The group means of each stimulus condition for the four participant groups is illustrated in Figure 2.5 below.

Figure 2.5 Group means for performance in the speech and non-speech conditions for the participants in experiments one and two



*Maximum score per condition = 16

T-tests were performed on the data collapsed across experiments one and two. Pair-wise comparisons amongst the groups (autism sample in experiment one versus autism sample in experiment two, and control sample in experiment one versus control sample in experiment two) across the two studies revealed that, overall, the children with autism (N = 47) exhibited indistinguishable performance in the speech condition (t (45) = -.23, n.s.). Furthermore, although the mean for the non-speech condition in experiment two was higher than that in experiment one, this difference failed to reach statistical significance (t (45) = -1.89, $p < .07$). To summarise, the two groups of children with autism exhibited very similar patterns of performance, and showed no significant cross-domain differences. The control children (N = 47) showed the same pattern of responding in the speech condition (t (45) = 1.05, n.s.). Here, however, the processing of pitch contour across synthesised and musical stimuli was significant (t (45) = -2.06, $p < .05$), with the children in experiment two performing significantly better with the non-speech stimuli (music) compared with the children in experiment one (synthesised speech). Thus, these findings suggested that the musical stimuli were easier to process than the synthesised speech stimuli. It is of interest here to refer back to the correlational data from both experiments. In experiment one, a strong positive relationship between performance in the intact and impoverished speech conditions for both groups was found, indicating a general ability to process pitch contours in vocal information. However, in experiment two, a relationship between performance levels in the speech and music conditions was only evident for the children with autism, indicating a *domain-general* ability to process pitch information. This correlation was found for children with autism from all levels of intellectual functioning. As age- and intelligence data did not differ across the participant groups, performance of the children when sub-divided by diagnosis was comparable across the two experiments, especially so in the shared speech condition.

As the hypothesis of experiment two was specifically formulated to test the core predictions of the weak central coherence (WCC) theory (Frith, 1989a; Happé, 1999), and the theory of enhanced perceptual functioning (EPF) (Mottron & Burack, 2001), stating that the enhanced perceptual processing in autism occurs at the expense of semantic processing, the individual children's perceptual versus semantic processing patterns were considered within the data from the autism group. Table 2.10 displays the proportion of children (in percentages) in the sample exhibiting four distinct processing styles. These categories were: children with high perceptual (65% correct or above) and high semantic ability (69% correct or above); children with high perceptual and low semantic ability (33% correct or below); children with high semantic and low perceptual ability (33% correct or below); and children with low perceptual and low semantic ability.

Table 2.10 Proportions of children (in %) within the autism sample falling within each of the four distinct processing categories

	High perceptual and high semantic ability	High perceptual and low semantic ability	High semantic and low perceptual ability	Low perceptual and low semantic ability
% of children in the sample	28	28	20	16

Table 2.10 shows that 56 per cent of the children in the autism sample showed enhanced perceptual processing, and 44 per cent of the children showed low semantic processing ability. However, only 28 per cent of the children in the sample exhibited a processing style that conformed to the predictions of the WCC and EPF theories. This will be discussed further. The remaining eight per cent of the children in the sample did not conform to any of the processing styles shown in Table 2.10.

DISCUSSION OF EXPERIMENTS ONE AND TWO

The findings from the experiments reported in this chapter reinforce conclusions that there is an enhanced sensitivity to pitch information in speech, speech-like, and musical stimuli in autism. The purpose of experiment one was to elucidate how enhanced musical pitch processing abilities in autism might influence such individuals' perception of speech stimuli, with and without semantic content. The findings showed that children with autism exhibited significantly better performance in both the semantically intact speech and semantically impoverished speech conditions in comparison to their age- and verbal intelligence matched controls. Both groups of children were better able to extract the pitch contours from the intact speech stimuli as compared to synthesised speech. The positive correlation between performance in the intact and impoverished speech conditions for both groups of children supported the idea of modularity behaviourally, suggesting that the processing of pitch contours in the two types of vocal stimuli utilised shared processing mechanisms. Whilst supporting the hypothesis that children with autism would show significantly heightened sensitivity to the pitch properties in auditory stimuli, these findings failed to support the following hypotheses. Firstly, that a reduced orientation towards semantic information in speech would enable children with autism to perform equally well in both experimental conditions. Secondly, that the typical orientation towards the meaning of speech would result in the control children showing lower levels of performance in the intact speech condition. As this experiment failed to clarify the role of semantic information in vocal stimuli, experiment two was carried out following paradigm modifications.

In experiment two, the semantically impoverished speech condition of experiment one was substituted with analogous musical contours. The findings from this study showed that children with autism performed at a significantly higher level in both the speech and music conditions compared with their age- and intelligence matched controls. Within-diagnosis comparisons showed that both groups of children exhibited equal levels of performance in the speech and music conditions. Thus, these findings failed to support the hypothesis that the typical semantic processing bias in the control children would interfere with such individuals' perception of pitch. However, the most striking finding was a correlation showing a strong positive relationship between performance in the speech and music conditions for the children with autism, whilst no such correlation was found for the control children. This finding suggested that the pitch processing abilities of the children with autism generalised from musical to speech information, and thus were domain-general. The analysis of the semantic processing data indicated that the children with autism showed significantly poorer ability to process speech for meaning compared to their matched controls. This is in line with previously reported findings (Frith & Snowling, 1983; Happé, 1997; Tager-Flusberg, 1991). When the data from high- and low-functioning children were analysed separately, the described pattern of results remained virtually unchanged. No statistically significant differences in pitch discrimination were observed between children with typical and lower than normal intellectual functioning, suggesting that pitch processing abilities are indeed robust against intellectual impairment. These results are consistent with findings reporting preserved pitch processing abilities in children with intellectual impairment (McLeish and Higgs, 1982) and Williams syndrome (e.g., Don et al., 1999). These results also showed that the children with high-functioning autism were significantly better at extracting the meaning of speech samples compared to the children with the low-functioning form of the disorder, and whilst semantic ability was associated with verbal intelligence for the whole autism sample, the high-functioning children appeared to rely on non-verbal cognitive abilities, that is, these children's score on the Raven's Progressive Matrices correlated with semantic ability. This finding suggested that in intellectually able children with autism, semantic processing may have been qualitatively different to that seen in typical development. It is interesting to note that a similar finding has been reported by Toichi and Kamio (2001), and led these authors to suggest that non-verbal intellectual abilities may actually be more important for semantic processing ability in individuals with autism than explicitly verbal intellectual abilities. Non-verbal intelligence was not significantly associated with pitch processing abilities in either group of children. Taken together, these findings reinforced conclusions that individuals with autism show enhanced sensitivity to perceptual information in speech, speech-like, and musical stimuli, and that this ability is independent of the level of intellectual functioning and semantic processing ability.

The finding that the children with autism showed significantly enhanced perceptual processing abilities in speech together with significantly compromised ability to process speech for meaning, may be interpreted within the framework of the weak central coherence (WCC) theory (Frith, 1989a; Happé, 1999) and the theory of enhanced perceptual functioning (EPF) (Mottron & Burack, 2001). Within the WCC theory, the enhanced pitch processing abilities in autism are explained by a local information-processing bias, such that it directly interferes with the processing of the global level semantic information. By contrast, according to the EPF theory, enhanced pitch processing abilities derive from over-developed low-level perceptual processes in autism, which in turn results in an under-development of higher-level cognitive processes that underpin global information-processing, such as semantics. However, when the data from individual children in the autism group was analysed with regard to their perceptual versus semantic processing ability, the results showed that only 28 per cent of the children exhibited a processing style that conformed to the predictions of the WCC and EPF theories. It was also surprising that a further 28 per cent of the children in the sample showed high-level ability in both the perceptual and semantic tasks, suggesting that the relationship between these two processes is not as straightforward as outlined by the WCC and EPF theories. Furthermore, the finding that semantic information did not interfere with the processing of perceptual level information in the control children was surprising; however, given that the performance of these children in the pitch task was lower throughout, it may be the case that semantic or global processing hampered such individuals' ability to process perceptual level information. Another possible explanation as to why the original hypothesis may not be true concerns the notion that typically developing children are accustomed to listening to music with lyrics. Here, they would indeed be expected to be able to attend to both the melody, and the linguistic content of the lyrics.

The finding that the children with autism from all levels of intellectual functioning showed domain-general ability to process pitch is important, as it provides evidence for qualitatively different processing of social and non-social stimuli in autism. One possibility is that this processing style is a down-stream effect of the early "neglect" of social stimuli in autism (Dawson et al., 1998; Klin, 1991). Further down-stream effects of this atypical developmental trajectory may be the higher-level semantic processing deficits that were highlighted by experiment two. It is possible that this pattern of findings reflects reduced specialisation in the neural mechanisms sub-serving the processing of speech and music in autism. The finding that the control children only showed similar performance between conditions across the intact and synthesised speech stimuli in experiment one, whilst no such correlation was found for speech and music stimuli in experiment two, might reflect more robustly modularised neural mechanisms within the speech and musical domains in these children. This is because the processing of the two types of vocal information in experiment one would indeed be expected to rely upon the neural mechanisms specific to speech. This possibility will be explored further in chapter four. Anecdotal evidence supporting the speculation that children with autism might be relying upon different mechanisms to their controls when resolving the pitch contour task was obtained. Specifically, a large number of children with autism hummed or sang (often with unintelligible words) the contour stimuli (intact and impoverished) to enable them to derive the melodic shape of the stimuli. Some control children repeated back the stimulus sentences, but had a great difficulty with reproducing the melodic contours.

One important finding that arose from the comparisons carried out on the data from high- and low-functioning subgroups was that showing chance level performance in the children with moderate learning difficulties in all eight stimulus conditions. A possible explanation for these results is that previous research has identified cross-modal matching deficits in children with specific language impairment (Boucher, Lewis, & Collis, 2000). It is thus possible that in this heterogeneous group of children, some exhibited auditory to visual mapping difficulties, which manifested in the low performance scores.

Chapter Three

Exploring Auditory Information-Processing in Autism: Is the Semantic Content of Speech Less Salient than its Perceptual Features?

Summary: In the experiment described in this chapter, children with autism and their matched controls were tested using a paradigm that directly compared the processing of perceptual (pitch) versus semantic components of speech samples. The aim of the study was to identify any response biases in speech processing. The participants were given a choice to respond to either perceptual or semantic features of short sentences. The findings indicated that although children with autism made significantly more perceptual judgements, and significantly fewer semantic choices than their matched controls, they did not show a strong perceptual bias. By contrast, the control children showed a strong bias towards responding to the semantic aspects of speech. The children with autism made significantly more accurate perceptual judgements than the controls, whilst the accuracy of

the semantic judgements did not differ between the groups.

INTRODUCTION

In the previously presented experiments, sensitivity towards pitch contour information across speech, speech-like, and musical stimuli was investigated. The findings from these studies showed that children with autism were significantly better at extracting pitch contours across speech, synthesised speech, and musical stimuli, compared to their matched controls. It was therefore established that their exceptionally good pitch analysis skills in the musical domain generalised to speech. Pertaining to the semantic domain, the findings from experiment two further suggested that enhanced pitch processing abilities in autism occurred together with significantly compromised semantic processing. However, as a subgroup analysis showed that only 28 per cent of the children in the sample exhibited a processing style that conformed to the predictions of the weak central coherence (WCC) theory (Frith, 1989a; Happé, 1999) and the theory of enhanced perceptual functioning (EPF) (Mottron & Burack, 2001), and that only 56 per cent of the children showed enhanced perceptual processing, the following experiment directly compared the processing of perceptual (pitch) versus semantic aspects in speech samples. Thus, the question to be asked in this chapter concerns the degree to which the enhanced perceptual processing of speech by individuals with autism might interfere with their attending to the semantic components of speech.

As was mentioned in the introductory chapter, young children with autism show developmentally atypical patterns of social attention. More specifically, studies have reported that children with autism show decreased orientation towards human speech and other social stimuli over non-social information (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Klin, 1991). This stands in striking contrast with typically developing infants, for whom the human voice is by far the most important auditory stimuli (Eisenberg, 1979). Indeed, their attending towards non-speech information is determined by how speech-like it appears (Butterfield & Cairns, 1976). In autism, the reduced salience of speech may manifest later as down-stream deficits in the higher-level semantic and pragmatic language functions (Tager-Flusberg, 2001a). It is interesting to note, however, that children with autism have been shown to be able to read for meaning if they are directly instructed to do so (Happé, 1994; Snowling & Frith, 1986), but that this does not appear to be the default mechanism. The experiment to be presented in this chapter will directly investigate the extent to which there might be a perceptual versus semantic "trade-off", such that the enhanced processing of perceptual aspects compromises the ability to process language for meaning in autism.

Based upon the findings from experiments one and two, the hypothesis for the following experiment states that children with autism will focus on the perceptual level of speech (i.e., pitch contour) instead of processing it for semantic content. Thus, this hypothesis will essentially test the core predictions of the weak central coherence (WCC) theory (Frith, 1989a; Happé, 1999) and the theory of enhanced perceptual functioning (EPF) (Mottron & Burack, 2001). Both accounts posit that autism is characterised by a cognitive bias towards local, perceptual level information, such that it results in reduced processing of information for global meaning. The stimuli will consist of 24 short sentences, in which will be embedded the four previously described pitch contours. Presentation of sentences will be followed by a visual display showing the correct pitch contour, an incorrect pitch contour, the correct semantic choice, and an incorrect semantic choice. Examples of response slides are shown in Figure 3.1. The participants will be asked to respond in a way that is most automatic and natural to them, and will be trained in such a way that the reinforcement of any specific response bias will be avoided. Since research has shown that semantic content in language has reduced salience for children with autism (e.g., Happé, 1997), and that the processing of language for meaning might not be their default mechanism (Happé, 1994), it is predicted that children with autism will consequently make more perceptual judgements and fewer semantic judgements of the speech stimuli, than their controls.

PITCHING SEMANTIC PROCESSING: A PILOT STUDY

In order to achieve semantic picture-sentence pairs that would be neither too easy nor difficult to resolve, test materials were piloted on typically developing children prior to constructing the actual test stimuli.

METHOD

Participants

Seven children of average academic ability were recruited from a mainstream primary school. The mean age of this group was 10 years, 3 months.

Stimulus materials

Thirty-six sentences were individually piloted along with a visual display consisting of three different semantic choices. One of the pictures was the correct target whist the two others were distracter items. The pictures were selected from the Peabody Picture Vocabulary Test (Dunn & Dunn, 1981), and each depicted a scenario of a possible event. The position of the target item was randomised across the sentences. The sentences were five or six syllables in length, and were read by a native female English speaker. The sentences were constructed in such a way that they did not directly name any of the objects that appeared in the pictures, but rather referred to the "situation" (e.g., for a sentence "It's dinner-time soon", the semantic choice might be between a picture depicting a woman peeling potatoes, one where a girl is wrapping a present, and one where a boy is climbing over a fence). The stimuli were presented on a laptop computer, and each auditory sample was followed by a different visual display.

Procedure

The children were tested individually in a quiet room in their own school. The experimenter explained that the child was going to hear some short sentences that were pre-recorded onto the computer, and that three pictures would appear on the screen after each sentence. The child was asked to point to the picture that s/he thought best matched the sentence.

RESULTS

As the chance rate of responding correctly in this task was .33, any items that yielded lower than a 50 per cent correct response rate across participants were eliminated. This resulted in 33 sentences. 24 of the highest scoring sentences were selected as test stimuli, and a further eight sentences to be used for training purposes.

EXPERIMENT THREE: THE AUTOMATIC PROCESSING OF SPEECH: THE SALIENCE OF PERCEPTUAL VERSUS SEMANTIC INFORMATION

METHOD

Participants

Twenty-five male and three female children with a formal diagnosis of an autistic spectrum disorder were recruited from two specialist educational establishments for children with autism. Some of these children had participated in experiment two (see appendix one for details). These children were aged from 7 years, 4 months to 16 years, 10 months (mean 12 years, 2 months, *SD* 2.47). Their standardised scores on the British Picture Vocabulary Scale (BPVS) ranged from 40 to 135 (mean 76, *SD* 28.19), and their raw scores varied from 30 to 142 (mean age equivalent 7 years, 9 months, *SD* 31.81). The control children were matched on an individual basis to those with autism for age and verbal intelligence. In this group, 20 male and eight female children were recruited from a mainstream primary school (seven children), a primary school for children with moderate learning difficulties (10 children), and a mainstream secondary school with a specialist unit for children with moderate learning difficulties (11 children). The ages of these children ranged from 7 years, 6 months to 16 years, 1 month (mean 12 years, *SD* 2.71). Their standardised scores on the BPVS varied from 40 to 124 (mean 75, *SD*

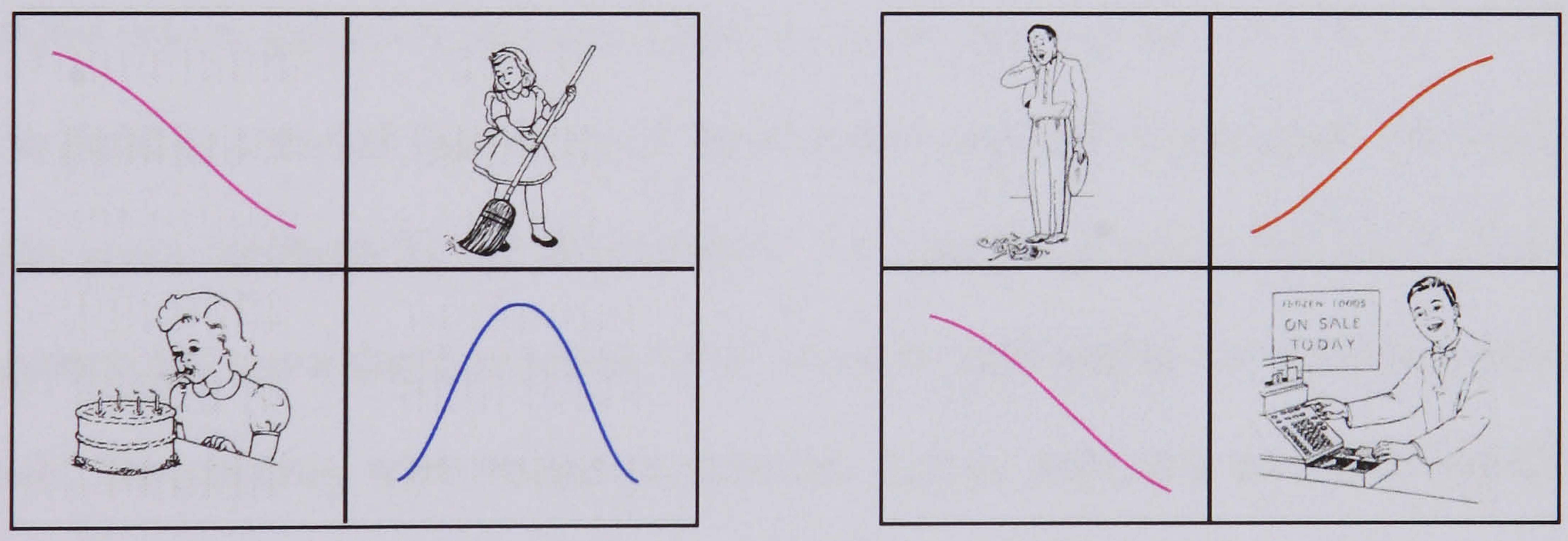
22.44), and their raw scores ranged from 34 to 129 (mean age equivalent 7 years, 11 months, *SD* 23.21).

Test stimuli

Training stimuli: Eight sentences, selected on the basis of the pilot study, were recorded directly onto a laptop computer. The speech samples were edited using the Praat speech editor (Boersma, 2001). Each sentence was uttered by a native English speaking female in such a way as to produce one of the four pitch contours described in chapter two (ascending, descending, low-high-low, high-low-high). These are shown graphically in Figure 2.1. Visual inspection of the F_0 curves was used to ensure that the contours were produced as intended; when needed, sentences were re-recorded until the desired contours were obtained. Four training blocks, using the eight sentences, were then built on a laptop computer. Perceptual training block (a) included four sentences of which each conformed to a different pitch contour. The presentation of each sentence was followed by a visual display depicting the four contours, shown in Figure 2.1. Perceptual training block (b) was constructed as described above, but used the remaining four sentences. Semantic training block (a) included the same sentences that were used in perceptual block (a), but here each sentence was followed by a screen depicting the correct semantic choice and an incorrect semantic choice (for materials, see pilot study). Correspondingly, semantic training block (b) included the same sentences that were used in perceptual training block (b). The position of the correct choice was randomised across the semantic training trials.

Experimental stimuli: 24 sentences, in which were embedded an equal number of four distinct pitch contours, were used in the actual test. They were uttered by the same female voice as in the training stimuli. The sentences were selected as described in the pilot study. The order in which the pitch contours appeared in the sentences was randomised across the test stimuli. Twenty-four visual response slides were then constructed, with each including the correct pitch contour symbol, an incorrect pitch contour symbol, the correct semantic choice, and an incorrect semantic choice. The two perceptual choices were located on screen in opposite corners (so as to be diagonally opposed to each other), and with each consecutive slide the two response modalities swap diagonals. Two examples of visual slides are shown in Figure 3.1. The positioning of the correct perceptual and semantic targets was randomised across slides. The task was constructed in such a way that each sentence was followed by a visual display.

Figure 3.1 Examples of visual slides used in the test stimuli of experiment three, for sentences (a) "I like growing older", and (b) "I will lose my job"



(a) (b)

Procedure

The experiment was carried out at the various participating schools. Each child was tested individually in a quiet room. The order of administering the four training blocks was counterbalanced across participants, but always in a way that no two same modality blocks were presented in succession. The child with autism and their individually matched control child always received the training blocks in the same sequence. Four possible training sequences existed: 1) perceptual training (a), semantic training (a), perceptual training (b), and semantic training (b); 2) semantic training (a), perceptual training (a), semantic training (b), and perceptual training (b); 3) perceptual training (b), semantic training (a), perceptual training (a), and semantic training (b); and 4) semantic training (b), perceptual training (a), semantic training (a), and perceptual training (b). For the perceptual training, the experimenter told the child that sentences could be read in such a way that they can form differently sounding "shapes", depending on how the "height" of the voice changes during the sentence. The training block of four sentences was then played, and the child was asked to match a contour symbol to the melodic shape of each sentence. The experimenter corrected any mistakes that the child made. For the semantic training block, the experimenter told the child that sentences also told a little story that could be depicted by a picture. This time the child was told that pictures would appear on the screen after each sentence, and that the child's task would be to point to a picture that in his/her opinion best matched the sentence. The child was again given feedback by the experimenter. For training given in the above described sequence, the remaining perceptual block would be followed by the remaining semantic block. The children were trained to criterion, that is, until they performed equally in both response modalities. Once the training phase was completed, the experimenter told the child that she had more similar sentences recorded onto the computer. This time the child would have a choice to either match the sentences to a contour symbol or to a picture that tells a story, but the child was asked to respond in a manner that was most automatic and natural to him or her. No feedback was given, and the experimenter recorded the children's responses.

RESULTS

The first analysis was carried out on the response choice data. The means and standard deviations for the number of perceptual and semantic choices made by the children with autism and their matched control children are displayed in Table 3.1.

Table 3.1 Means and standard deviations for the response type choices for both the children with autism and their matched controls

	Number of perceptual choices		Number of semantic choices	
	Mean	**SD**	**Mean**	**SD**
Autism group (N=28)	8.46	7.40	15.54	7.40
VIQ- and age-matched controls (N=28)	1.46	3.17	22.54	3.17

*Maximum score per condition = 24

As the experimental hypothesis stated that children with autism would make more perceptual judgements of the stimuli than their matched controls, a one-way analysis of variance was carried out on the perceptual choice data in order to compare performance between the two groups. It was only necessary to perform the analysis for one set of the choice data as the categories were mutually exclusive. This analysis revealed a significant effect of group (F (1, 54) = 21.19, $p < .001$), with the children with autism making significantly more perceptual choices compared with the control children. However, a pair-wise t-test revealed that the children with autism still made significantly more semantic than perceptual judgements of the stimuli (t (27) = -2.53, $p < .02$), and the control children made significantly more semantic than perceptual choices (t (27) = -17.6, $p < .001$). Thus, just over one third of the responses made by the children with autism were to the perceptual aspects of stimuli. The percentages of children making each type of judgements were then calculated. This analysis showed that, whilst 86 per cent of children with autism made at least one perceptual judgement of the stimuli, only 39 per cent of the control children did so. All the children (N = 56) made at least one semantic response choice. Overall, this inspection suggests that the children with autism showed more heterogeneous patterns of responding.

As the standard deviations for the children with autism were very large for both response-type modalities (7.40 versus 3.17 for the control children), the distribution of data within each response category was examined. Table 3.2 displays the ranges of scores for perceptual and semantic response categories for both groups of participants.

Table 3.2 Ranges of scores within perceptual and semantic response choice categories for both the children with autism and their controls

	Range of perceptual scores		Range of semantic scores	
	Minimum	Maximum	Minimum	Maximum
Autism group (N=28)	0	23	1	24
Controls (N=28)	0	13	11	24

* Maximum score per condition = 24

As Table 3.2 shows a large difference in ranges of scores between the children with autism and their controls, Figure 3.2 illustrates box plots of the distribution of scores within the perceptual response choice category for the children with autism and their controls, and Figure 3.3 shows box plots of the distribution of data within the semantic response choice category for the two groups of participants.

Figure 3.2 Box plots of data distribution within the perceptual response choice category for the children with autism (left) and their controls (right)

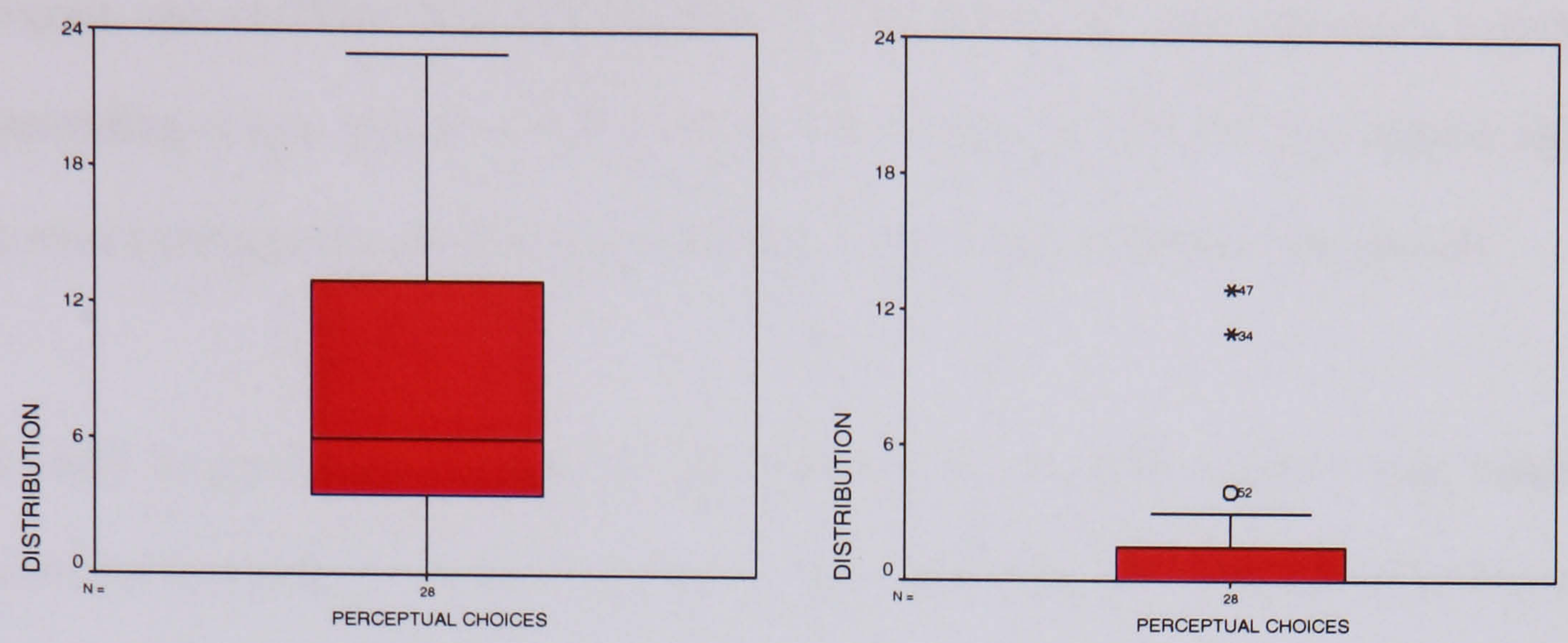
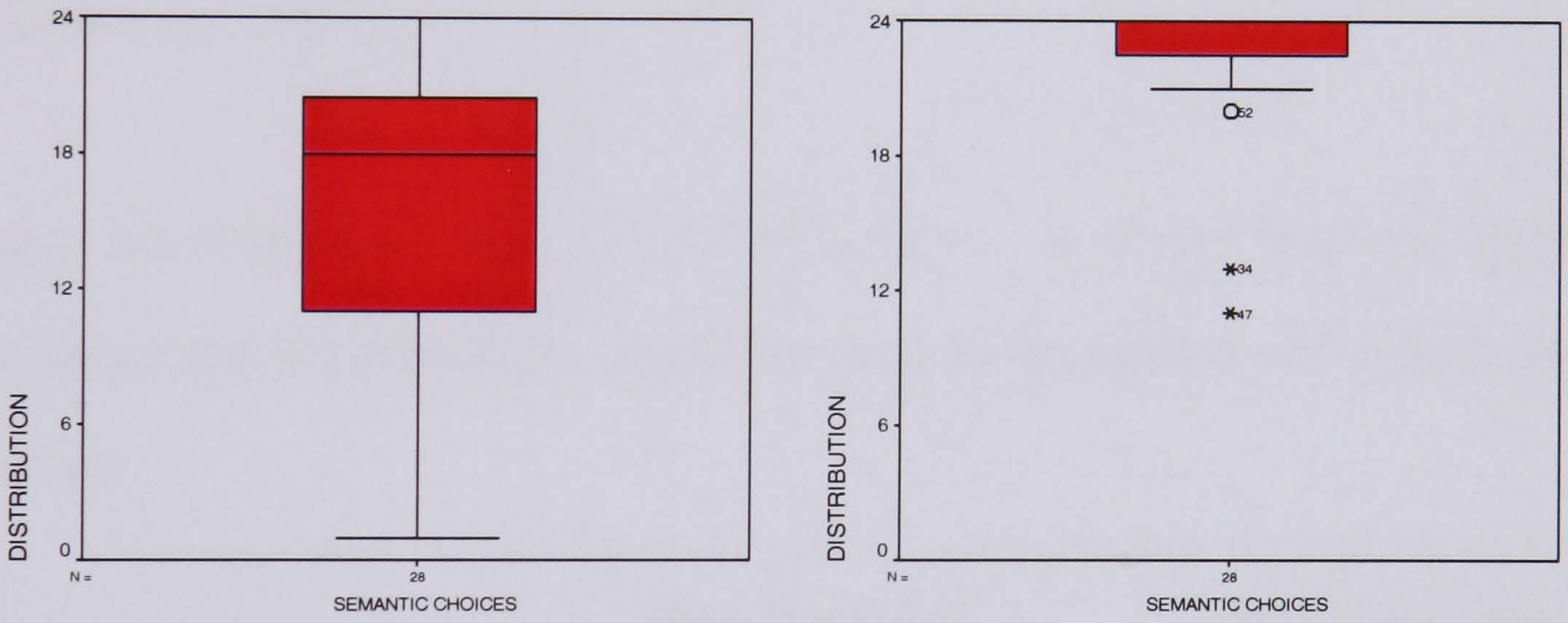


Figure 3.3 Box plots of data distribution within the semantic response choice category for the children with autism (left) and their controls (right)



Figures 3.2 and 3.3 above illustrate that the data distributions were particularly skewed for the children in the control group. Within the control group, a subgroup of three children were identified, who showed bias towards responding to the perceptual aspects of the stimuli, and correspondingly, as the categories are mutually exclusive, a reduced tendency to respond to the semantic content of speech, relative to the other control children. The most extreme outliers (i.e., cases 34 and 47) showed levels of performance that were three standard deviations above the group mean in the perceptual choice category, and correspondingly, three standard deviations below the group mean

in the semantic category. Case 52 showed a pattern of performance that deviated one standard deviation from the overall group performance. This will be further discussed. Overall, the children with autism showed highly variable and haphazard patterns of responding across the two choice modalities, whilst in contrast, the control children showed a strong bias towards responding to the semantic content of the stimuli.

In order to explore differences in response accuracy in both response type modalities (perceptual/semantic), each child's correct perceptual and semantic identification scores were converted into percentages correct out of the total number of choices made. The means and standard deviations for the mean percentages of correct judgements made in each choice modality for the children with autism and their matched controls are presented in Table 3.3.

Table 3.3 Means and standard deviations for the % correct responses within the perceptual and semantic choice modalities for both the children with autism and their controls

	Mean % accuracy of perceptual judgements			Mean % accuracy of semantic judgements		
	N	Mean	SD	N	Mean	SD
Autism group	24	73.62	26.83	28	72.00	28.49
VIQ- and age-matched controls	11	44.76	39.54	28	81.99	12.75

*Maximum = 100%

As can be seen from Table 3.3, the children with autism made substantially more correct perceptual judgements than their matched control children. An independent samples t-tests confirmed this observation (t (33) = 2.54, p < .02). The accuracy percentages for the children with autism showed that they were equally accurate in their perceptual and semantic judgements (*t* (23) = .17, n.s.), whilst the control children had a significantly poorer accuracy in their perceptual responses in comparison to their semantic ones (*t* (10) = -3.0, $p < .02$). An independent samples t-test carried out on the semantic accuracy data showed that the performance of the children with autism was not significantly different from that of the control children (*t* (54) = -1.69, n.s.). Thus, the children with autism did not show semantic processing deficits in comparison with their matched controls in this study, although they made significantly fewer semantic choices. This will be discussed further. The accuracy data for individual children were inspected further. This showed that whilst in the perceptual domain, for both groups of children, accuracies ranged between zero and 100 per cent correct, in the semantic domain, the lowest accuracy for the control children was 45 per cent correct. This contrasts with zero per cent for two of the children with autism. It is also noteworthy that in the perceptual domain, only one child with autism had an accuracy of zero per cent correct, whilst four control children did so. Taken together, these findings suggest that although the mean accuracies in the semantic domain did not differ between the groups, the children with autism showed considerably more "extreme" patterns of performance with regard to responding to the semantic components of stimuli when compared with their matched control children.

Finally, correlations were carried out between the age, verbal intelligence, and accuracy data. This analysis showed that for the children with autism, accuracy in the semantic responses correlated positively with verbal intelligence ($r = .43$, $p < .04$), suggesting that children with a higher verbal ability made more accurate semantic judgements of the stimuli compared to those with lower verbal intelligence. Furthermore, a significant positive relationship emerged between the perceptual accuracy data and age ($r = .56$, *p*

$< .005$), indicating that older children with autism made more accurate perceptual judgements as compared with the younger children. All other correlations for the children with autism were not significant. For the children in the control group, a significant positive correlation emerged between the semantic accuracy and age ($r = .52$, $p < .005$), suggesting that older control children achieved more accurate semantic judgements than did younger children. All other correlations failed to reach significance.

DISCUSSION

The results from experiment three indicate that, under experimental conditions which give a choice to respond to either perceptual or semantic features of speech, children with autism do in most cases choose to process speech at the semantic level. Thus, the experimental hypothesis stating that children with autism would choose to respond more often to the perceptual, rather than semantic aspects of speech was not supported. However, taken together, the findings provide evidence of a weakened default mechanism in speech processing in autism, as such children made significantly more perceptual judgements of the stimuli than their controls, and correspondingly, the children in the control group made significantly more semantic judgements of the sentences than did their counterparts with autism. Thus, the speech processing mechanism in autism was qualitatively different to that seen in the controls. Indeed, the control children showed an extremely robust bias towards processing speech at the semantic level, whilst within the autism group, strikingly heterogeneous patterns of responding were evident in both response modalities.

As the bias in speech processing in autism was substantially weaker than that observed for the controls, the data were inspected for the accuracy of the children's responses within both response choice domains. The rationale for doing so was to examine whether the choice responses might mask different processing abilities within the perceptual and semantic domains between the children with autism and their controls. This analysis revealed, firstly, that children with autism made significantly more accurate perceptual judgements than their matched controls, supporting the findings from experiments one and two, and those from musical pitch processing studies (e.g., Bonnel, Mottron, Peretz, Trudel, Gallun, & Bonnel, 2003; Heaton, 2003; Heaton, Hermelin, & Pring, 1998; Mottron, Peretz, & Ménard, 2000). Secondly, a striking finding was that the children with autism were equally accurate in their semantic judgements as compared to their controls. This finding is surprising in the light of the semantic processing deficits that are commonly associated with autism (Frith & Snowling, 1983; Happé, 1997), together with findings from experiment two, where such impairments were found. However, it is important to note that in this study, children with autism made significantly fewer semantic choices than the controls, and furthermore, it may be that those with autism responded very selectively to the semantic content. More specifically, they might have chosen only to respond to the stimulus items that they felt they could tackle. For the children with autism, verbal intelligence correlated positively with accuracy in the semantic domain, whilst this was not the case for the children in the control group. As 33 per cent of the sample comprised children with low-functioning autism (and a corresponding proportion of children with moderate learning difficulties in the control group), this finding suggests that the high-functioning children with autism were more competent at semantic processing as compared to those with a low-functioning form of the disorder. This finding is in line with the results obtained from experiment two, and with those of Miranda-Linné and Melin (1997).

The finding that no semantic deficits were in evidence in the current study, where children were given a choice to respond to either semantic or perceptual features, whilst such impairments were found in experiment two, where all children were asked to respond semantically, might simply reflect the abilities of children with autism who showed competent semantic processing. This is to say that it may be the case that only the children with relatively competent semantic ability chose to respond to the meaning of the speech items, and these may have been particular stimuli that these children found easy. In support of this are the findings from experiment two, showing that when forced to respond to speech semantically, children with autism showed marked deficits in semantic processing. In contrast, when given a choice to either respond to perceptual or semantic features of speech, no semantic processing deficits emerged in such children. Nevertheless, this result is in line with those obtained by Happé (1994) and Snowling and Frith (1986), showing that the ability to process language semantically is intact at least in some children with autism, whilst at the same time, it may not be their primary response mode. Furthermore, although training was carried out in such a way as to try and minimise any response biases, it is possible that, since the stimuli only consisted of intact speech items (cf. experiments one and two), and the paradigm pitted the processing of perceptual and semantic information directly against each other, some children with autism found it more natural to orient towards the meaning of the sentences. It is also of importance here to consider the validity of the paradigm used, particularly in the light of the fact that children with autism are specifically trained and taught to orient towards the meaning of speech in their specialist schools. It has been observed that if children with autism show difficulties in understanding speech, their teachers use picture aids to improve comprehension. Furthermore, there are anecdotal reports from speech therapists stating that, in order to maximise the probability that children with autism will understand speech, prosodic variations should be kept to minimum. Thus, these observations suggest that prosodic pitch variations do indeed capture such children's attention, and interfere with their ability to access the semantic content in speech. It might be speculated then, that the children with autism might therefore have been conditioned to "disobey" their natural instinct to attend to the perceptual levels of speech. There is anecdotal evidence in support of this speculation from some of the children who participated in the experiment. For example, one boy with normal verbal and non-verbal intelligence achieved 100 per cent correct in the training phase in both semantic and perceptual conditions. However, when told that in the actual experiment, the task would be to respond in a way that was most automatic, he checked several times with the experimenter whether it was "equally correct" to respond to the perceptual aspects as to the semantic content. Although this boy is verbally fluent and does not appear to have marked semantic deficits, he was consistently amongst the highest scoring children in the perceptual task of experiment two.

It is important here to consider the finding that within the control group, a subgroup of three children were identified, who showed a bias towards responding to the perceptual features of the stimuli. An inspection of the details of these children revealed that the least significant outlier (case 52) was an eight-year-old typically developing child. Her performance deviated one standard deviation from the overall group performance. The two most extreme outliers (cases 34 and 47) were children with moderate learning difficulties. However, these children did not have any diagnosis, and their language abilities appeared normal. These children showed a pattern of performance whereby the number of perceptual choices made was three standard deviations above the mean group performance. Correspondingly, the number of semantic judgements made by these children was three standard deviations below the group mean. These findings may seem less surprising if they are considered in the light of evidence showing preserved pitch processing abilities in children with intellectual impairment (McLeish & Higgs, 1982) and in children with Williams syndrome (Don, Schellenberg, & Rourke, 1999; Lenhoff, 1996). Furthermore, findings from experiment two indicated that pitch processing abilities are indeed robust against intellectual impairment. However, an inspection of the accuracy of these children's perceptual responses revealed that the maximum accuracy obtained was 50 per cent, whereas all children showed semantic accuracy of over 90 per cent. Thus, although these children showed a pattern of performance which resembled that of some of the children with autism, the accuracy of their perceptual answers was significantly below that achieved by the children with autism. Conversely, the accuracy of these children's semantic responses was greater than that obtained by the autism group. Thus, whilst it is difficult to draw any specific conclusions about the nature of the speech processing mechanism in autism, it is clear from the findings that children with autism showed a semantic bias that was significantly weaker than that seen in the control children. Furthermore, the children with autism exhibited significantly stronger perceptual bias, and their accuracy in this domain was substantially greater than that seen in the controls. Importantly, in the light of the subgroup findings described above, it seems evident that children with moderate learning difficulties may also show a reduced semantic bias, but that in such cases, this speech processing style is not accompanied by enhanced perceptual processing. This suggests that the superior perceptual processing was very specific to the children with autism in this study.

Further support for the weakened default mechanism in autism was obtained from the data showing that, when the mean accuracy scores in the perceptual and semantic domains were considered together, the children with autism showed a higher accuracy in their responses overall, although they made considerably more cross-domain responses than the controls. This high cross-domain accuracy in autism suggests that such children were strikingly more flexible in their on-line speech processing compared with their matched controls. This finding may indeed reflect down-stream effects of the atypical developmental trajectory in autism, whereby early selective attention towards social information is substantially reduced (Dawson et al., 1998; Klin, 1991). The findings from this study may be well accommodated within the enactive mind model (Klin, Jones, Schultz, & Volkmar, 2003), which suggests that the markedly reduced salience of social information in autism leads to enhanced specialisations being formed in a range of physical instead of social stimuli. The findings that the semantic processing speech bias was significantly reduced, whilst the processing of the linguistically meaningless pitch contours in such stimuli was significantly enhanced, in the autism group, provide support for this model.

Another explanation for the enhanced performance of the children with autism in this study might be that it simply reflects the fact that they were more aware of the details of the stimuli than their controls. Indeed, within the framework of the weak central coherence (WCC) hypothesis (Frith, 1989a; Happé, 1999) and the theory of enhanced perceptual functioning (EPF) (Mottron & Burack, 2001), the current findings of enhanced featural processing would be explained by a local information-processing bias (WCC) or by an over-development of low-level perceptual processes (EPF). However, the present finding showing intact semantic processing ability in the children with autism challenges these theories, as both models would predict deficits in global-level processing. Indeed, as was shown by the analysis of the individual children's data in the autism sample in experiment two, the relationship between perceptual and global level processes in autism appear to be more complex than is suggested by these models. Specifically, this analysis showed that, whilst 56 per cent of the children showed enhanced perceptual processing, and 44 per cent showed low semantic ability, only 28 per cent of the children in the sample exhibited a processing style that conformed to the predictions of the WCC and EPF theories. Furthermore, an important finding was that 28 per cent of the children in the autism sample exhibited enhanced perceptual abilities alongside competent semantic processing. This finding is in line with the current results. Also consistent with the findings from the present experiment, studies investigating musical pitch processing in autism have reported preserved ability in such individuals to process musical contours holistically (Foxton, Stewart, Barnard, Rodgers, Young, O'Brien, & Griffiths, 2003; Heaton, in press; Heaton, Pring, & Hermelin, 1999; Mottron et al., 2000). The WCC and EPF models have been criticised for failing to provide clear definitions of global or domain-general processes, and research studies have operationalised these differently, which has led to a great deal of confusion. The finding from the current study, that children with autism showed intact semantic processing ability, may reflect the fact that the semantic task used was not "global" enough. It remains to be seen whether the current findings could be replicated with a more demanding semantic processing task.

Chapter Four

Representation of Vocally and Musically Expressed Identical Pitch Sequences

EXPERIMENT FOUR: IS AUTISM ASSOCIATED WITH REDUCED NEURAL SPECIALISATION IN AUDITORY PROCESSING? COMPARING THE DISCRIMINATION OF IDENTICAL PITCH SEQUENCES ACROSS SPEECH AND MUSIC DOMAINS

Summary: Children with autism and their age- and intelligence matched controls were tested for their ability to judge whether the pitches in the second of a pair of auditory stimuli differed from the first. Three different stimulus conditions were presented: (1) speech versus speech, (2) music versus music, and (3) speech versus music. The results from this experiment showed that the children with autism were significantly superior compared to their controls in judging pitch sequences in both speech versus speech, and speech versus music stimulus pairs, whilst no group differences emerged in the condition where both stimulus pairs were music. The findings are discussed in the context of reduced

modularity in the pitch processing mechanisms
serving speech and music in autism.

INTRODUCTION

Findings from the previously reported studies (experiments one, two and three) indicated that children with autism showed significantly higher levels of performance in processing four different pitch contours across speech, synthesised speech, and musical stimuli, compared to matched control children. This effect has been observed in situations where their tendency to process speech semantically has been shown to be significantly reduced in comparison to their matched controls. These findings are interesting in the light of previously outlined neuroconstructivist models of development (Elman, Bates, Johnson, Karmiloff-Smith, Parisi, & Plunkett, 1996; Karmiloff-Smith, 1998; Johnson, 2000; 2001). One prediction from these models is that a reduced early bias towards the sampling of social information in autism would result in weakened neural specialisations being formed in the social domain. This is because, in typical development, the existence of innate biases is assumed to drive the subsequent emergence of specialisations (or modularisation) in neural mechanisms (Johnson, 2001). In the introduction to this thesis it was noted that deficits in joint attention behaviours (Mundy, Sigman, & Kasari, 1990; 1993), in later emerging meta-representational ability (Baron-Cohen, 2000), and in semantic and pragmatic language processing (Tager-Flusberg, 2001b) are commonly seen in autism. If interpreted within the context of neuroconstructivist models, these could be seen as down-stream effects of the often observed "neglect" of social stimuli (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Klin, 1991). Indeed, recent influential theories of autism, namely the enactive mind model (Klin, Jones, Schultz, & Volkmar, 2003), and the componential model of theory of mind (Tager-Flusberg, 2001a), have proposed just such an explanation.

Correlational analysis conducted on data from experiment two, showing that unlike their controls, children with autism exhibited enhanced domain-general ability to process pitch information across speech and music, provides some evidence for qualitatively different processing of social (speech) and non-social (musical) auditory stimuli in autism. This could be seen as arising from reduced specialisations in the neural mechanisms sub-serving speech and music. This finding is consistent with neurological evidence. For example, abnormal brain mapping for both speech and tones in autism, in comparison to age-matched controls, has been found (Müller, Behen, Rothermel, Chugani, Muzic, Mangner, & Chugani, 1999). Indeed, the findings from this positron emission tomography (PET) study showed a right hemisphere shift in participants in autism in response to incoming speech sounds. Consistent with this, a PET study carried out by Boddaert et al. found right hemisphere dominance in participants with autism in response to synthetic speech-like stimuli, whilst typical controls showed the reverse pattern of activation (Boddaert, Belin, Chabane, Poline, Barthélémy, Mouren-Simeoni, Brunelle, Samson, & Zilbovicius, 2003). Thus, these data suggest a reversed hemispheric dominance in autism, suggesting that speech information is largely processed in the right hemisphere in such individuals. A cortical event-related brain potentials study found a reduced salience of the "speechness" quality of sounds in participants with autism, indicating speech-selective attentional deficits at the biological level (Čeponienė, Lepistö, Shestakova, Vanhala, Alku, Näätänen, & Yaguchi, 2003). Finally, a functional magnetic resonance imaging (fMRI) investigation reported abnormal cortical processing of speech in autism (Gervais, Belin, Boddaert, Leboyer, Coez, Sfaello, Barthélémy, Brunelle, Samson, & Zilbovicius, 2004). As no abnormalities were found in the perception of non-vocal sounds in participants with autism, relative to age-matched controls, the authors suggested that these findings may reflect an attentional bias towards non-social auditory stimuli in autism, which may result in enhanced processing of musical pitch. In the light of these findings, it could be speculated that individuals with autism treat speech and musical stimuli more similarly than do those with typical development.

One reason why individuals with autism show greater difficulties processing speech, relative to music, could be that auditory filters are broader than normal in individuals with autism (Plaisted, Saksida, Alcántara, & Weisblatt, 2003). One implication of such an abnormality would be that such individuals perceive speech as being more monotonic than do those with typical development. Furthermore, as fundamental frequency variations are less discrete in speech than in music, this may explain why individuals with autism often show difficulties with receptive and expressive prosody, whilst their processing of musical pitch is good or superior. However, as findings from experiments one, two, and three showed that children with autism were equally able to process pitch contours in speech and musical stimuli, the hypothesis to be tested in the following experiment states that children with autism will show equal performance in judging pitch sequences across speech versus speech, music versus music, and speech versus music stimulus pairs.

Although research into prosodic processing in autism has highlighted difficulties in understanding pitch-mediated linguistic cues in speech (see McCann & Peppé, 2003;

Van Lancker, Cornelius, & Kreiman, 1989; Rutherford, Baron-Cohen, & Wheelwright, 2002), persistent and marked deficits have also been described at the semantic level of language (Simmons & Baltaxe, 1975; Tager-Flusberg, 2001b). These findings contrast with those showing intact or superior musical pitch processing in autism relative to age- and intelligence matched controls (Bonnel, Mottron, Peretz, Trudell, Gallun, & Bonnel, 2003; Heaton, 2003; Heaton, Hermelin, & Pring, 1998; Heaton, Pring, & Hermelin, 1999; Mottron, Peretz, & Ménard, 2000). Findings from experiment two showed that for those with autism, the ability to process pitch information in music generalised to the processing of linguistically "meaningless" pitch contours in speech to a substantially greater extent than was the case for controls. Moreover, they chose to process for purely perceptual content more often than their controls, for whom a strong default mechanism to process speech for meaning (see experiment three) may mean that perceptual details that are linguistically non-functional have very limited salience.

Whilst contour processing in speech and musical information might be very similar early in development, experience with these types of stimuli would be expected to cause increasing specialisation across domains. With regard to pitch, there is evidence to indicate that pitch processing is initially a domain-general process. For example, young infants have been shown to acquire representations of pitch sequences regardless of whether the stimuli are speech or music (Saffran, Johnson, Aslin, & Newport, 1999), suggesting that similar mechanisms are utilised in both domains initially. Models of neurodevelopment would predict that the processing of the two classes of stimuli become increasingly less similar during the course of development. Such models have been built upon the idea of modularity of cognitive function (e.g., Fodor, 1983). Fodor's theory assumes that there are separate modules or processing units for speech and music, which are domain-specific, and operate automatically in the presence of the appropriate information. Studies of patients with acquired brain damage, in whom the brain insult has selectively impaired musical processing abilities whilst leaving speech processing abilities intact, and vice versa (e.g., Ayotte, Peretz, & Hyde, 2002; Yaqub, Gascon, Al-Nosha, & Whitaker, 1988), have been taken as evidence for both of these modules possessing the property of neural specificity (Peretz & Coltheart, 2003). However, a study by Patel and colleagues has found that amusic patients with bilateral brain damage shared neural mechanisms when processing contour information in both speech and music (Patel, Peretz, Tramo, & Labreque, 1998). Thus, it appears that at certain neural levels, the processing of linguistic and musical pitch shares resources in the brain.

Following from this, Peretz and Coltheart (2003) proposed that there may be a "contour analysis" component, whereby pitch sequences are abstracted from both speech intonation as well as music. In their modular theory of musical processing, each sound initially enters an acoustic analysis module, which is domain-general. Whether this sound will cause subsequent activation in the speech or music processing module is assumed to be determined by the feature of the auditory stimulus to which the module is tuned (Coltheart, 2001). Previous evidence showing atypical speech processing in autism (Boddaert et al., 2003; Gervais et al., 2004; Müller et al., 1999) might then suggest that the speech processing module is faulty and fails to activate in the presence of such information.

Pertaining to the variants of modular theories, more recent connectionist models of development (see Karmiloff-Smith, 1998; Karmiloff-Smith & Thomas, 2002) can potentially explain the observed patterns of atypical auditory processing in autism from a developmental perspective. Here, all neural networks are assumed to be learning systems, whereby a number of initial constraints, present prior to the onset of learning, drive the course of development. Thus, selective deficits observed in autism would be explained in terms of shifts in these initial constraints. One such shift might be in the module serving the processing of speech. Furthermore, according to this conceptualisation, the relationship between domain-specific and domain-general processes is an interactive one: all processes begin as domain-general, but when combined with the initial constraints and shifts in such constraints for specific domains, specialisations emerge as a result of interaction with the learning environment. Thus, all networks begin with a certain structure but no representational content, and become gradually modularised as a result of learning. It follows that atypical networks are considered not to contain any deficits prior to learning (Karmiloff-Smith & Thomas, 2002).

In the light of the findings from the previously cited studies, together with those from experiment two, it would follow that the neural organisation for processing pitch contour information in speech and music might be less neurally specific and thus less modularised in autism compared with typical development. Johnson (2000; 2001) has usefully extended the aforementioned model of Karmiloff-Smith and colleagues to explain the development of neural organisation in the brain. Of central importance to this model is the large cortical volume in humans, together with the prolonged post-natal period during which interaction with the learning environment can influence the tuning of the brain's circuitry (Johnson, 2001). The typical social information input bias has obvious evolutionary value, and it follows that the early biased sampling of such information might ensure the appropriate specialisation of the subsequently developing brain circuitry (Ibid.). In the light of the earlier speculation about reduced biased sampling of social information in autism, it would indeed follow that the speech or language module, feeding on social input, would fail to specialise to the extent seen in typical development. Relating this speculation to the evidence, it has indeed been found that individuals with developmental disorders exhibit abnormalities in interaction and connectivity between different brain regions (Johnson, 2001). For example, structural imaging studies have found abnormalities in both white and grey matter in autism (Courchesne, Karns, Davis, Ziccardi, Carper, Tigue, Chisum, Moses, Pierce, Lord, Lincoln, Pizzo, Schreibman, Haas, Akshoomoff, & Courchesne, 2001; Filipek, Richelme, Kennedy, Rademacher, Pitcher, Zidel, & Caviness, 1992). In typical development, changes in grey matter volume are proposed to indicate cortical pruning, whilst changes in white matter reflect inter-regional connectivity, reflecting brain specialisations (Johnson, 2001). In autism, the proportionally over-developed non-verbal, perceptual, and cognitive abilities relative to verbal and social functioning, have been suggested to reflect increased neuronal growth and decreased cortical pruning (Cohen, 1994; Happé, 1999). Indeed, Deutsch and Joseph (in press) identified a link between large head circumference and particularly discrepant cognitive profiles in children with autism. Thus, the structural brain abnormalities in autism are likely to reflect input aberrations. In summary, the findings from experiment two, showing a domain-general pitch processing ability in autism, and an explanation based on reduced innate biases, resulting in atypical and insufficient learning experiences, can be well accommodated within this framework.

Finally, cognitive theories of autism, within which the findings showing enhanced perceptual processing and compromised semantic processing in autism could be interpreted, include the weak central coherence (WCC) theory (Frith, 1989a; Happé, 1999) and the theory of enhanced perceptual functioning (EPF) (Mottron & Burack, 2001). The WCC theory would predict that the enhanced perceptual processing abilities are attributable to a local processing bias resulting from a top-down deficit in central coherence, whilst the EPF theory would consider such abilities stemming from abnormal development of low-level perceptual processes. Subsequently, weak central coherence has been hypothesised to directly interfere with the processing of socially relevant or global level information, such as semantics, whilst the EPF model has been proposed to involve an under-development of higher-level cognitive processes that underpin global information-processing. The findings from experiments one, two, and three, showing enhanced pitch processing abilities, together with a significantly compromised tendency to focus on semantic information, are consistent with the predictions of both the WCC and EPF theories. Whilst the WCC and EPF accounts would predict a domain-general superiority in autism across stimulus classes, an abnormal modularisation hypothesis states that similar performance in autism will be seen across different stimulus types. In contrast, for the controls, differences will emerge in the treatment of the different stimulus types.

To address the experimental hypothesis, the experimental stimuli will consist of three conditions: those of speech-speech, music-music, and speech-music auditory pairs. These stimulus pairs will either share the exact four-pitch sequences, or differ in two pitches only, in such a way that the pitch sequence in the second of a pair maintained the contour of the first of the pair. Children with autism and their age- and intelligence matched controls will be asked to make same/different discriminations of the stimulus pairs.

METHOD

Participants

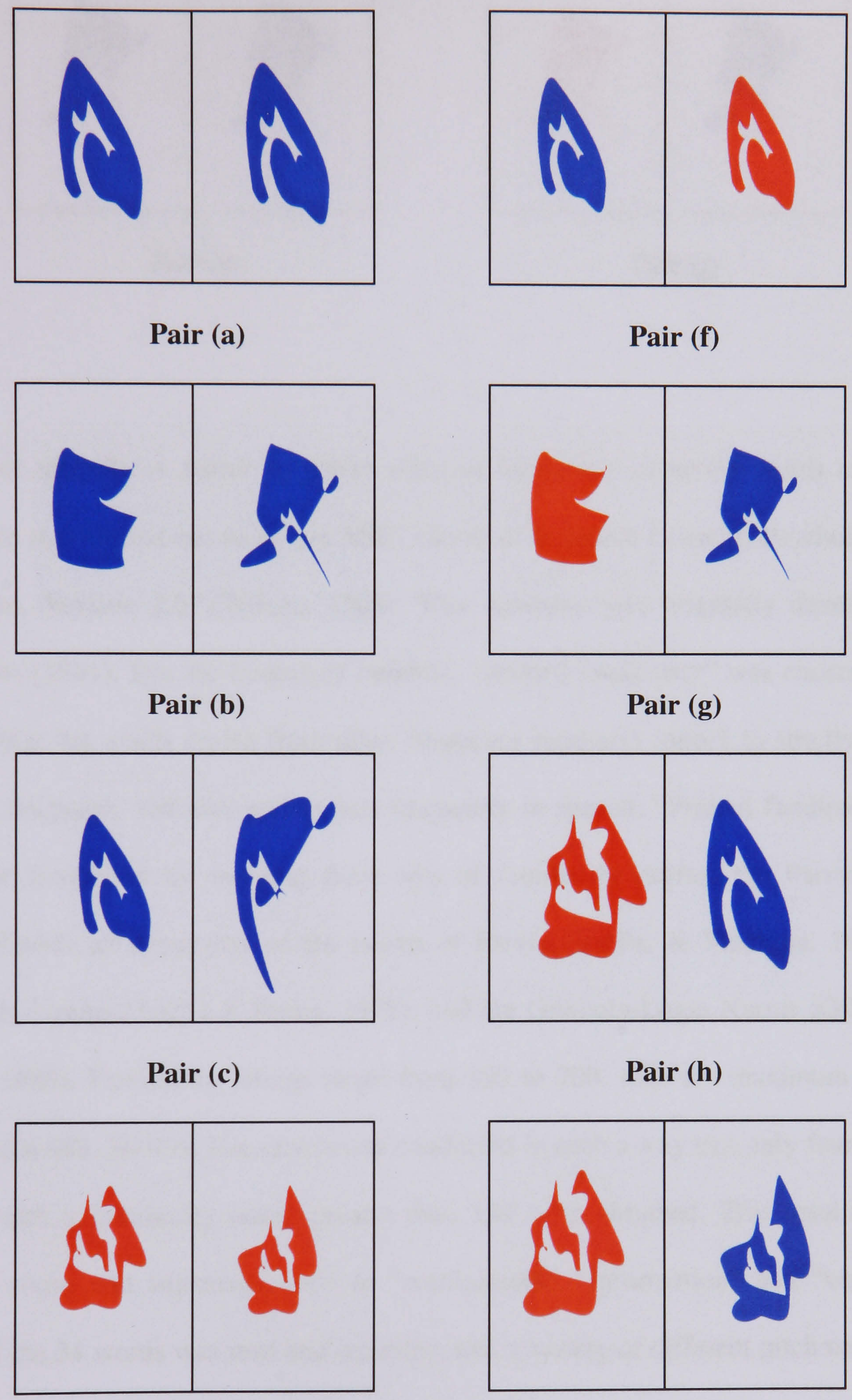
Twenty male, and three female children with a formal diagnosis of an autistic spectrum disorder participated in this study. Seventeen children were recruited from a specialist educational establishment for children with high-functioning autism, and further six children were recruited from a school catering for children with moderate learning difficulties. Some of these children had participated in experiments two and three (see appendix one for details). These children were aged from 7 years, 9 months to 16 years, 11 months (mean 12 years, *SD* 2.46). Their standardised scores on the British Picture Vocabulary Scale (BPVS) ranged from 42 to 135 (mean 84, *SD* 23.12), and their raw scores ranged from 31 to 142 (mean age equivalent 8 years, 5 months, *SD* 27.39). Their standardised scores on the Raven's Standard Progressive Matrices varied from 66 to 119 (mean 90, *SD* 12.24, mean MA 10 years, 10 months). The control children were matched on an individual basis to those with autism for age, verbal, and non-verbal intelligence. In this group, 17 male and six female children were recruited from a mainstream primary school (eight children), a primary school for children with moderate learning difficulties (six children), and a secondary school for children with moderate learning difficulties (nine children). These children were aged from 7 years, 11 months to 16 years, 5 months (mean 12 years, 5 months, *SD* 2.50). Their standardised scores on the BPVS ranged from 44 to 124 (mean 83, *SD* 21.62), and their raw scores ranged from 58 to 128 (mean age equivalent 8 years, 10 months, *SD* 19.19). Their standardised scores on the Raven's Matrices varied from 61 to 121 (mean 82, *SD*

16.33, mean MA 10 years, 2 months). The two groups of children did not significantly differ on any of the matching parameters.

Stimuli and experimental design

Training stimuli: Ten pairs of visual figures, illustrated in Figure 4.1 below, were used to train participants. Pair (a) illustrates a pair where the figures are both the same shape and the same colour, and pairs (b) to (e) depict pairs that are of same colour but are different in shape. The degree of difference between the different pairs decreases gradually from pair (b) to (e), with the figures in pair (e) being most similar to each other. Pair (f) depicts a pair where the shapes are the same but they are of different colour. The purpose of using pairs in which the colours of the shapes were different was to draw the participants' attention to the fact that the shapes can be the same although the colours are not; this is an analogue of the speech versus music condition used in the current experiment, where the pitch information can be the same across different stimulus classes. Pairs (g) to (j) depict pairs in which both the colour and the shapes are different. Again, the degree of difference between the pairs decreases gradually from pair (g) to (j), with the shapes being most alike in pair (j).

Figure 4.1 Visual figure pairs used for training in experiment four



Pair (a)

Pair (b)

Pair (c)

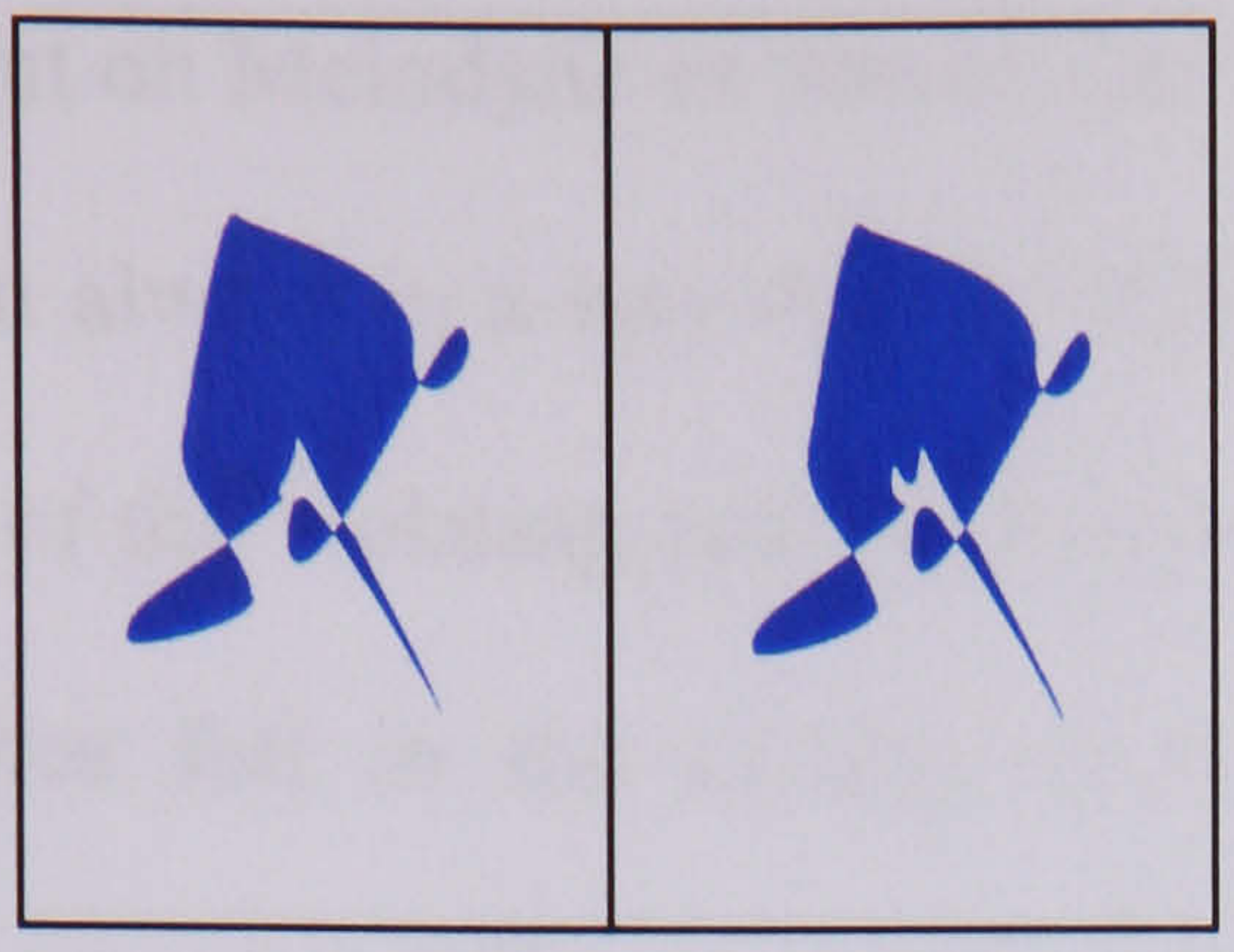
Pair (d)

Pair (f)

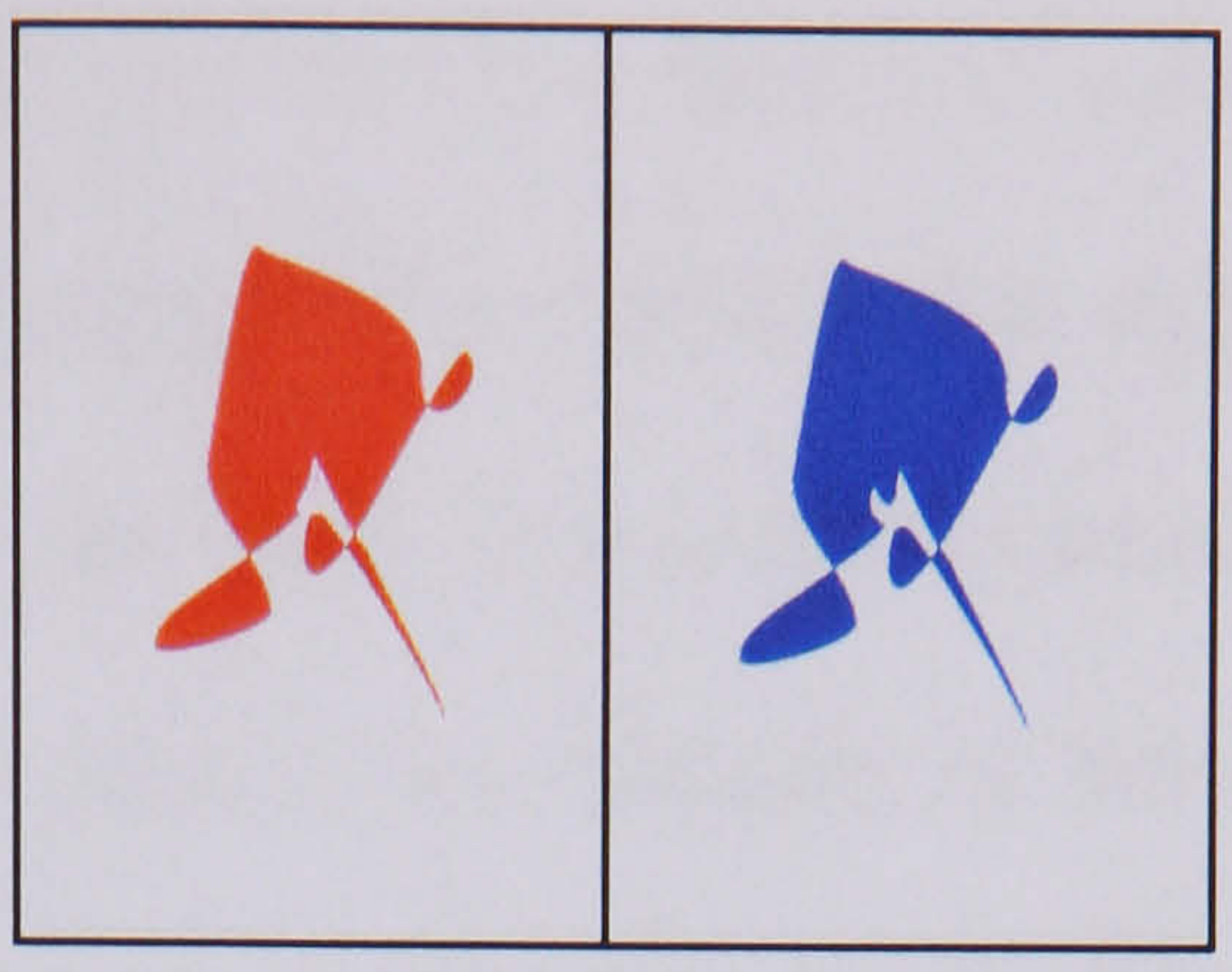
Pair (g)

Pair (h)

Pair (i)

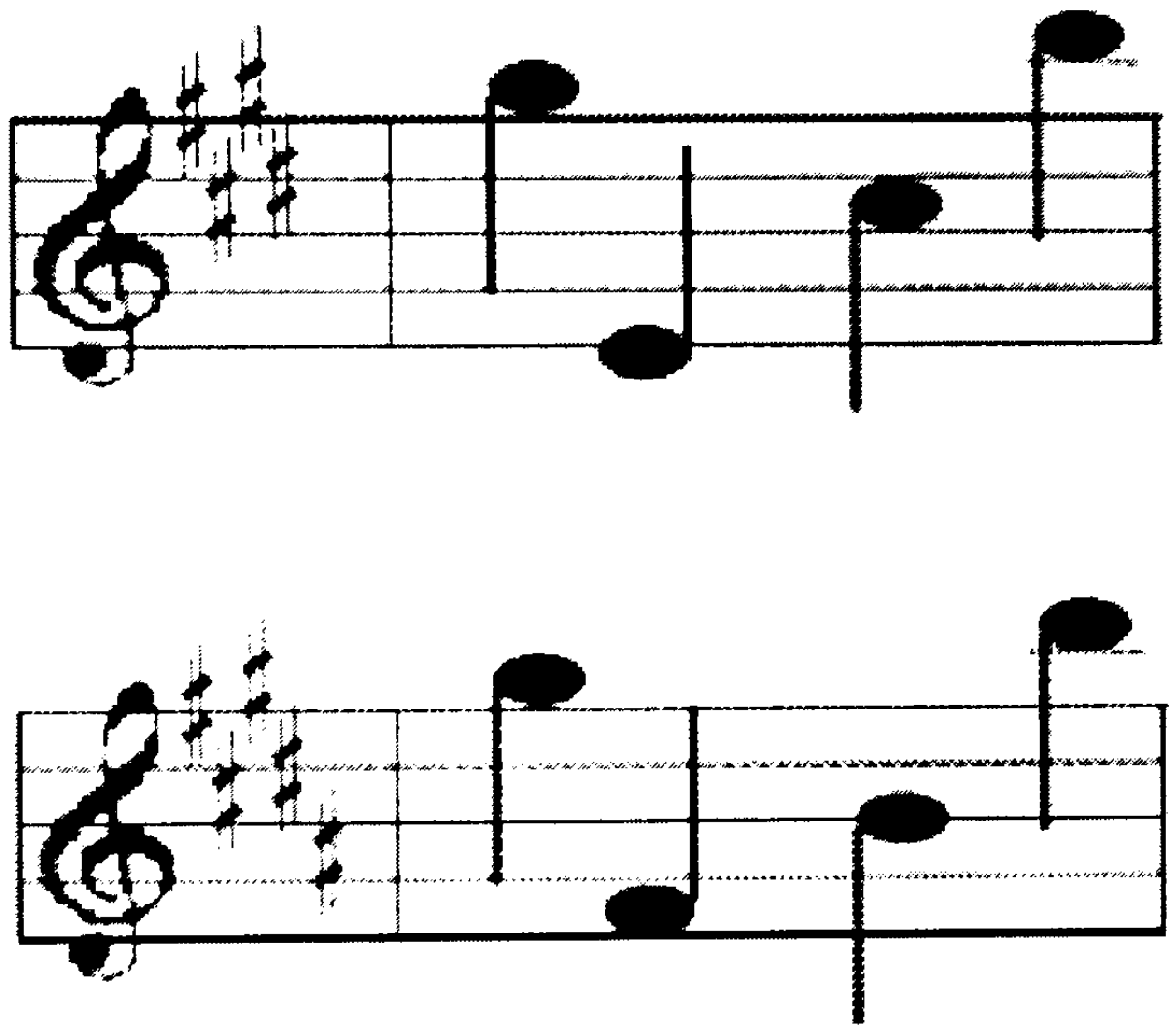


Pair (e)



Pair (j)

Auditory stimuli: A search to derive a list of frequently occurring words in spoken language was carried out using the MRC (Medical Research Council) Psycholinguistic Database, Version 2.0. (Wilson, 1988). This database was originally developed by Coltheart (1981). For the frequency measure, "printed familiarity" was chosen for the reason that the words drawn from other frequency measures tended to strictly refer to written language, and thus appear less frequently in speech. "Printed familiarity" is a measure developed by merging three sets of familiarity norms: the Paivio Norms (unpublished; an expansion of the norms of Paivio, Yuille, & Madigan, 1968); the Colorado Norms (Toglia & Battig, 1978); and the Gilhooly-Logie Norms (Gilhooly & Logie, 1980). Familiarity ratings range from 100 to 700, with the maximum entry of 657 (mean 488, *SD* 99). The search was conducted in such a way that only four-syllable words with a familiarity rating greater than 550 were obtained. This resulted in 34 neutral nouns and adjectives, such as "comfortable", "information" and "vegetable". Each of the 34 words was read and recorded with a variety of different pitch trajectories by a native English speaking female. The exact pitch patterns of the words were then traced using the Melodyne software package (Neubäcker & Gehle, 2003). Twelve same word pairs (total of 24 items) were selected on the basis the similarity of their pitch and timing characteristics (all single notes were crochets). Some pitch modifications were carried out on Melodyne so that all the "different" pairs had two same and two different tones, but always in a way that the different notes maintained the contour, and that the position of the violating pitches was not first or last notes. It was also ensured that all the pitches fell in the middle of the tone regions. An example of the musical composition of a different pair ("responsible 1" and "responsible 2") is illustrated in Figure 4.2.

Figure 4.2 Example of the melodic composition of a "different" pair ("responsible 1", top, and "responsible 2", bottom) used in experiment four

Twenty-four four-tone musical forms, which shared exactly the same pitch and timing properties as the speech samples, were then created using a Casiotone 202 electronic keyboard (acoustic piano setting). Their exact melodies were again traced by Melodyne to ensure that their pitch and duration patterns were identical to those of the corresponding speech samples. For the speech versus speech condition, 12 "same" pairs were constructed using half of the speech stimuli, using the GoldWave software package (www.goldwave.com) simply by inserting the same auditory information twice into a sound file, each pair being separated by one-second gaps. For the "different" pairs, the two different melodic forms of the same words were inserted into sound files, again separated by one-second gaps. This "different" condition shared half of the stimuli used in the "same" pairs. The pairs for the music versus music condition were created as described earlier, using the corresponding musical samples. For the speech versus music condition, to control for "order effects", the speech condition preceded the musical form in half of the stimuli, and vice versa in the other half. Twelve "same" and twelve "different" pairs were created as described above. Thus, for example, for a "different" pair where the speech segment was "responsible 1", the musical form would be that of "responsible 2". Thus, the stimuli in all three conditions were musically identical.

The procedure described above resulted in a total of 72 stimulus pairs. The order of the stimulus items was randomised. The test stimuli were constructed as a PowerPoint presentation.

The paradigm applied to the auditory stimuli, as described above, was originally developed by Dowling (1978), and was adapted in this study to prevent ceiling performance from occurring in situations where the stimulus pairs were different. It is well established that contours, comprising of sequences of single pitches, or melody, is the most perceptually salient aspect of music. However, studies have shown that the constituent single pitches are relatively unimportant in contour perception, especially when the musical material is unfamiliar (Deutsch, 1972), as was the case in the present study. It has been suggested that when listening to unfamiliar melodies, the overall global contour shape is encoded, rather than the single pitches (Dowling, 1978).

Research in this area has further shown that, if the overall contour shape of a pair of different melodies which include some different single pitches is maintained, the contour pairs sound similar (Ibid.).

Procedure

The children were tested individually in a quiet room in their own school. A training phase preceded actual testing. Firstly, the children were presented with the visual slides of figure pairs shown in Figure 4.1, starting with the slide (a) where the figures are the same in both shape and colour. The experimenter asked the child to say what s/he noticed about the figures (same/different colour; same/different shape). Once the child gave a correct answer, the pair (b) where the two figures are most different were shown. The child was again asked to comment on them. The remaining three slides (c-e) were presented in an order where they became progressively more similar. The experimenter corrected the child where necessary. The same procedure was then carried out for the slides (f-j), in which the shapes are of different colour, to draw the child's attention towards the "figural" similarities. Once the visual training was complete, the experimenter explained: "Now we are going to do the same with things that we listen to. You are going to hear some pairs of sounds, and sometimes they will only be very little different, sometimes very much different, and sometimes the same. So, we are going to listen to pairs of sounds, and you will need to decide whether they sound the same or different. Sometimes we are going to hear a voice speaking and a piano playing, but that doesn't necessarily mean that they will be different. In fact, they can be the same, and so you will need to listen carefully whether their *tune* is the same or not. Let's listen to a pair, and please tell me whether you think the pairs have the same or a different tune". The experimenter then played the first item of the actual test stimuli, and recorded the child's response. The test was divided into two blocks of 36 items, with a three-minute pause in between. To avoid "fatigue effects", the order of presentation of the two stimulus blocks was counterbalanced across participants. The control children received the test blocks in the same order as their autistic counterparts.

RESULTS

The means and standard deviations for the correct identification of speech-speech, music-music, and speech-music pairs for the children with autism and their control children are displayed in Table 4.1.

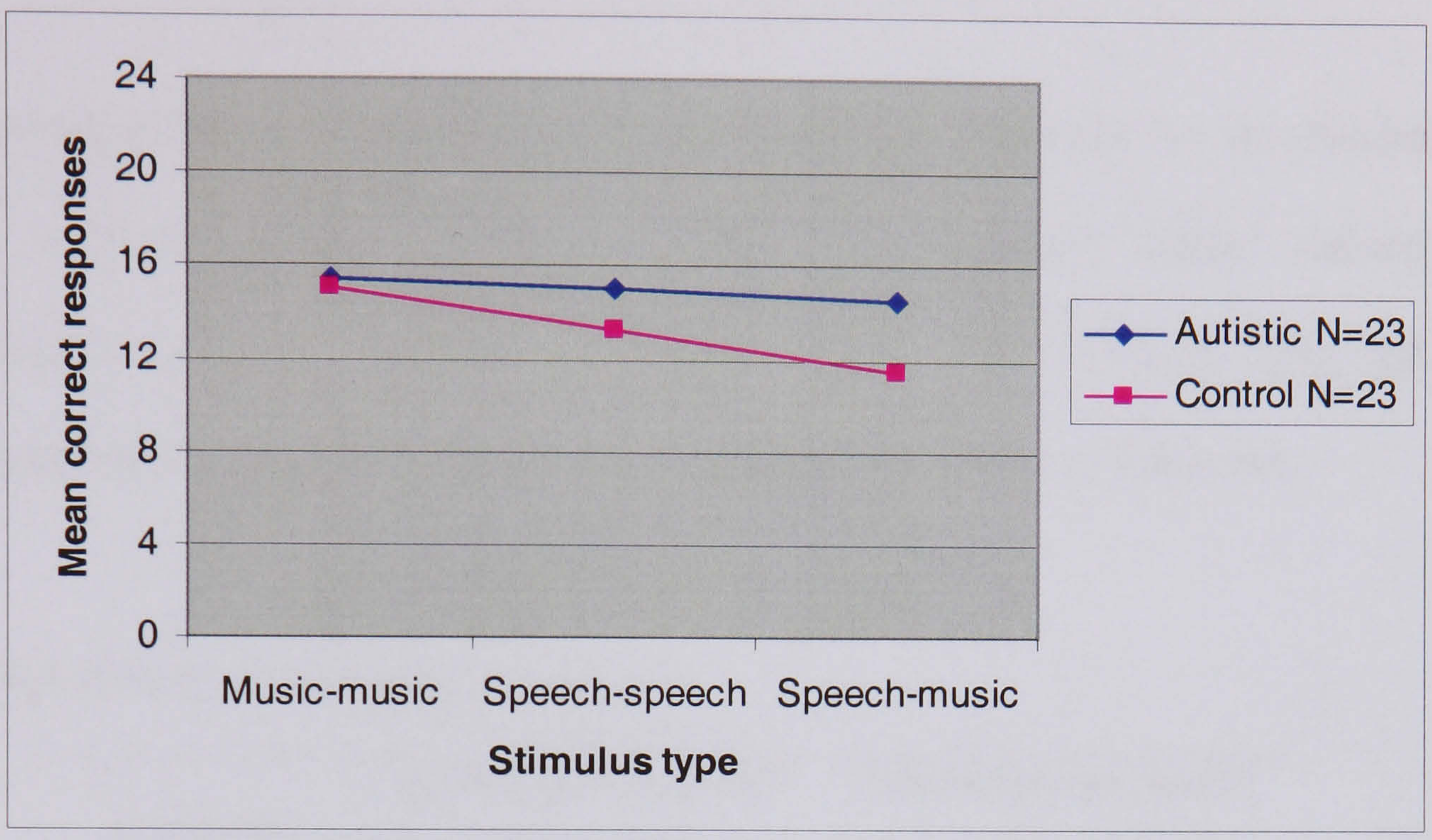
Table 4.1 Means and standard deviations for the correct identification of the stimulus pairs in the three experimental conditions for both the children with autism and their matched controls

	Music-music		Speech-speech		Speech-music	
	Mean	SD	Mean	SD	Mean	SD
Autism group (N=23)	15.35	3.30	15.00	2.68	14.52	2.71
VIQ-, NVIQ- and age-matched controls (N=23)	15.04	3.47	13.22	2.26	11.48	1.20

*Maximum score per condition = 24

A three by two repeated measures analysis of variance with stimulus type (speech-speech, music-music, and speech-music) as the within-participants factor, and diagnosis (autistic/control) as the between-participants factor, was performed on the data. This analysis revealed a highly significant main effect of stimulus type (F (2, 88) = 8.64, p = .001), with best performance occurring in the music-music condition; a main effect of diagnosis (F (1, 44) = 8.59, p = .005), with children with autism showing superior performance overall; and a stimulus type by diagnosis interaction (F (2, 88) = 3.27, $p <$ .05), as illustrated in Figure 4.3.

Figure 4.3 Means for correctly identified music-music, speech-speech, and speech-music pairs by the children with autism and their matched controls



*Maximum score per condition = 24

The interaction was subjected to further analysis using t-tests. Pair-wise comparisons of the main effect means across groups revealed that the children with autism showed significantly higher levels of performance in the speech-speech (t (44) = 2.44, p < .02) and speech-music (t (44) = 4.92, p < .001) stimulus pairs compared with that of their control children. There was no significant between-group difference in children's performance in the music-music condition (t (44) = .31, n.s.). Pair-wise comparisons amongst the groups revealed that for the children with autism, performance was equal across the speech-speech and music-music pairs (t (22) = -.50, n.s.), speech-speech and speech-music pairs (t (22) = .76, n.s.), and music-music and speech-music (t (22) = -1.01, n.s.) pairs. Thus, the children with autism showed no difference in performance across the three conditions. The same comparisons for the control children revealed that their performance was significantly higher in the music-music pairs compared with speech-speech pairs (*t* (22) = -2.77, *p* < .015), in the speech-speech pairs compared with speech-music pairs (*t* (22) = 3.87, *p* = .001), and in the music-music pairs compared with the speech-music pairs (*t* (22) = -5.14, *p* < .001).

The mean performance scores for the three stimulus conditions for the children with autism and their matched control children were checked against chance level performance (12) by applying one-sample t-tests. The t-values (22) and their corresponding *p*-values for both groups of children are shown in Table 4.2.

Table 4.2 Results of one-sample t-tests

Condition	Autism group (N=23)		Control group (N=23)	
	t-value (22)	p	t-value (22)	p
Speech-speech	5.37	<.001	2.59	<.02
Music-music	4.87	<.001	4.21	<.001
Speech-music	4.46	<.001	-2.08	<.05

Table 4.2 shows that both groups of children showed levels of performance that were significantly different from chance (12), with performance being better than chance with all three types of stimulus pairs except with the speech-music stimuli for the controls, which was significantly below chance.

Finally, correlations were performed between verbal intelligence score and performance in the three experimental conditions, between non-verbal intelligence score and performance in the three experimental conditions, and between total scores for each of the three types of stimulus class. For the control children, verbal intelligence correlated positively with performance in the music-music condition (*r* = .45, *p* < .04), but not with performance in the speech-speech (*r* = .11, n.s.), and speech-music condition (*r* = -.02, n.s.). There was a positive relationship between non-verbal intelligence and performance in the music-music condition (*r* = .66, *p* = .001), but not with performance in the speech-speech (*r* = .21, n.s.), and speech-music condition (*r* = .22, n.s.). None of the correlations for between-condition performance were significant for the controls (music-music with speech-speech (*r* = .35); music-music with speech-music (*r* = .29); speech-speech with speech-music (*r* = .28)). For the children with autism, verbal and non-verbal intelligence did not correlate with performance in any experimental condition. Two correlations for between-condition performance were approaching significance. Namely, performance in the speech-speech condition was positively associated with performance in the music-music condition (*r* = .39, *p* < .07), and performance in the speech-music condition was positively associated with performance in the speech-speech condition (*r* = .37, *p* = .08).

DISCUSSION

The aim of this study was to examine the possibility that a reduction in the early biased sampling of socially relevant information in autism might result in reduced specialisations developing in the neural mechanisms sub-serving the processing of speech and music in such individuals. It was hypothesised that for children with autism, the "speechness" quality of sounds will not appear to activate "special" or differential processing from that of non-speech sounds (Gervais et al., 2004), and that they would show equal performance in judging the pitch sequences in the speech versus speech, music versus music, and speech versus music conditions. The findings from this experiment indicated, firstly, no between-group differences in performance in the music-music condition. However, correlational analysis showed that good performance in the control children with these stimuli was significantly associated with both verbal and non-verbal intelligence. As no such correlations were evident for the children with autism, this suggests that the children with autism utilised qualitatively different processing mechanisms to the controls when processing musical pitch. Secondly, the most striking finding was that the high levels of performance in contour discrimination in the children with autism generalised to speech-speech, and to cross-domain speech-music stimuli. Indeed, no statistical differences in performance across the three stimulus classes were found for these children. By contrast, the control children showed a substantial decrease in performance when pitch contour discriminations involved speech stimuli. Indeed, their levels of performance in the cross-domain speech-music condition was significantly lower than chance. Finally, correlational analysis showed that for the children with autism, correlations between performance in the speech-speech and music-music condition, and between performance in the speech-speech and speech-music condition were approaching significance. No such trends were evident for the children in the control group. Thus, this suggests that the pitch-processing abilities of the children with autism were less dependent on the stimulus type than was the case for the control children.

As was mentioned in the introduction to this thesis, individuals with autism have often been noted to possess enhanced musical pitch processing abilities (e.g., Bonnel et al., 2003; Heaton et al., 1998; 1999; Mottron et al., 2000). However, in this study, no significant group differences in pitch sequence judgements of purely musical stimulus pairs were seen. This indicates that in the control children, the ability to process pitch was as good as that of their age- and intelligence matched autistic counterparts, but that this ability was highly dependent on the stimulus class. However, the current findings from the music-music condition are consistent with recent findings showing no differences between individuals with autism and age- and intelligence matched controls in processing musical pitch contours (Foxton, Stewart, Barnard, Rodgers, Young, O'Brien, & Griffiths, 2003; Heaton, in press). The finding of intact contour processing in autism has been proposed to disprove the predictions of the WCC theory (Frith, 1989a; Happé, 1999) (Mottron et al., 2000). However, Foxton and colleagues reported evidence of abnormal global processing in individuals who processed contours typically, and Heaton (in press) found enhanced local processing of music in participants who showed normal processing of global contours. Clearly this paradigm is limited in the extent to which it isolates local and global processes within music. In the light of the current findings showing significantly enhanced processing of pitch information in speech and cross-domain speech-music stimuli in autism, and no between-group differences in performance with purely musical stimuli, it may be suggested that the atypical perceptual processing in autism is more social in origin than is allowed for by the WCC and EPF theories.

The finding of enhanced pitch processing abilities in speech stimuli in autism are important given the literature reporting prosodic processing abnormalities in such individuals (see McCann & Peppé, 2003, for a recent review). When the current findings are considered together with those reported for experiments one and two, showing enhanced processing of "linguistically independent" pitch variations in speech and speech-like stimuli in autism, and accompanying semantic processing deficits, it might be argued that enhanced perceptual processing in autism relates to the impoverished ability to process speech for higher-level meaning. However, an analysis of individual children's data in the autism sample of experiment two showed that only 28 per cent of them exhibited this type of processing profile, and more importantly, that a further 28 per cent of the children showed enhanced perceptual processing alongside good semantic processing ability. Thus, it seems evident that in some children, enhanced perceptual processing and higher-level linguistic competence are associated with each other. This will be further examined in chapters six and eight.

The finding that the children with autism showed equally good performance across stimuli pairs belonging to the same and different domains reinforce the conclusions that the processing of auditory information is qualitatively different in autism from that found in controls. More specifically, these findings provide behavioural evidence for the hypothesis that the neural organisation sub-serving the processing of pitch contour information in speech and music is less neurally specific in autism than that in typical development. In the current experiment, the cross-domain speech-music condition directly tapped onto these two different processing modules. The finding that the control children showed their poorest performance in this condition provided evidence for the suggestion that in typical development, the processing of pitch in music and speech are robustly neurally specific or modularised. The neuroconstructivist models of development (Elman et al., 1996; Johnson, 2000; 2001; Karmiloff-Smith, 1998; Karmiloff-Smith & Thomas, 2002) assume that specialisations emerge as neural networks are trained, that is, they are shaped by an individual's interactions with a learning environment. Atypical networks are assumed to be initially unimpaired in terms of knowledge, and behavioural impairments are expected to emerge after the networks are trained. In the light of the current findings, it seems plausible to suggest that the learning experience in autism is fundamentally different due to the absence of innate biases. This, in turn, would result in an aberrant early information input, which would subsequently shape the brain circuitry to specialise atypically. It is of relevance here to consider the findings of Gervais et al. (2004). In this study using functional magnetic resonance imaging (fMRI), the cortical activation patterns of adults with autism and age-matched healthy controls were measured in response to voice and non-voice stimuli. The findings showed that the activation patterns of the autism and control groups did not significantly differ in response to non-voice stimuli, indicating normal cortical processing of non-speech information in autism. Strikingly, however, the participants with autism failed to show activation in the voice-selective regions of the cortex in response to the voice stimuli. Thus, these findings of voice-specific cortical processing abnormalities in autism further support the idea that cortical specialisation for speech is reduced. It has been suggested that these findings may reflect speech-selective attentional abnormalities in autism; indeed, a study by Čeponienė et al. (2003), using event-related brain potentials, confirmed the existence of such deficits. These findings showing speech-sound specific attentional and cortical processing deficits are consistent with the hypothesis that there may be a reduction, or indeed an absence of innate biases towards socially relevant information in autism (Klin et al., 2003). The findings from this study, together with those obtained from the other experiments reported in this thesis, will be discussed further in the final chapter of this thesis.

Chapter Five

Sensitivity to Rhythm Patterns in Speech in Children with Autism

EXPERIMENT FIVE: INVESTIGATING THE SENSITIVITY TO SYLLABIC RHYTHM PATTERNS IN INTACT SPEECH AND PSEUDO-SPEECH STIMULI

Summary: In the following experiment, children with autism and their matched controls were tested for their ability to extract four different syllabic rhythm patterns from short intact speech and vowel sound (pseudo-speech) samples, matched for duration. The processing of the intact speech stimuli for meaning or was assessed by control questions. The results showed that the children with autism were equally good at extracting the rhythmic patterns from both intact speech and pseudo-speech stimuli, whilst the control children performed significantly worse in the intact speech condition. The performance in the pseudo-speech condition was indistinguishable between the two experimental groups. Furthermore, the control children were

significantly more proficient at processing the intact sentences at the semantic level than the children with autism.

INTRODUCTION

The studies reported in the previous chapters (experiments one, two, three, and four) showed that, when compared with age- and verbal intelligence matched controls, children with autism showed a significantly higher sensitivity towards pitch information in vocal stimuli, whilst their processing of the speech samples for meaning was compromised in experiment two. Although the findings from experiment three failed to reveal semantic processing deficits in autism, the results from this study showed that such children exhibit a reduced semantic speech processing bias. Whilst pitch is an important component of prosody, the reported studies investigated pitch processing in a context where it did not serve any intended communicative function. As rhythm is another important component of prosody, a pilot study examining the processing of rhythmic patterns in speech in autism was carried out. The rationale for this experiment was that investigations of individuals with congenital language disorder show that the processing of pitch and rhythm can dissociate (Alcock, Passingham, Watkins, & Vargha-Khadem, 2000), and damage to the rhythmic processing system can be seen alongside intact pitch processing abilities. Thus, the question to be asked in this chapter concerns the processing of rhythmic information in speech and speech-like stimuli, in children with autism and their age- and verbal intelligence matched controls, and how such abilities may be different from those in the domain of pitch.

Although rhythm, like pitch, is associated with both speech and music, an analogous aspect that would be applicable to both domains is difficult to formulate (Patel, Peretz, Tramo, & Labreque, 1998). This is because no universally accepted definition of rhythm exists in either domain. However, theorists generally agree that rhythm could be conceptualised as a division between grouping and meter (see Lerdahl & Jackendoff, 1983, for a discussion). In brief, grouping refers to the clustering of neighbouring components temporally into larger elements, whilst meter is a periodic temporal-accentuation. Since the experiment to be reported in this chapter will not attempt to contrast rhythmic processing across speech and music, syllabic rhythm will be used. According to Ramus and Mehler (1999), this is the most simplistic and perhaps the most fundamental cue for prosodic rhythm. It is noteworthy here that a neuropsychological investigation of patients with bilateral brain damage (Patel, Peretz, Tramo, & Labreque, 1998) found evidence for shared neural resources in the brain for the processing of not only pitch contour, but also rhythm patterns, across comparable linguistic and musical stimuli. The linguistic stimuli used in this study incorporated focus-shift pairs; that is, pairs of otherwise identical sentences that only differed on contrastive stress or focus. Thus, these sentences only differed in "punctuation" so that the meaning of the sentence pairs was subtly different.

The understanding of the linguistic function of rhythm is crucial to the ability to process speech at a meaningful level. The temporal sequence of speech sounds reflects an organisation according to functional complexity. At its simplest level, the temporal sequence of speech sounds signifies syllables, whilst at a higher level it interacts with the syntactic and prosodic aspects of the linguistic system (Bailey, Plunkett, & Scarpa, 1999). Thus, the concept of prosodic rhythm is complex, as it assumes several different functions. As the rhythmic quality of the speech stream results from the temporal organisation of pauses, stressed syllables, and unstressed syllables (Snow, 2001), a keen awareness of timing is necessary to process rhythmic prosody. Individuals with autism have been reported to show general deficits in their awareness of time and other temporal processing functions (e.g., Diamond, Dobson, & Boucher, 1998), but it is not known how these deficits might relate to their speech processing abilities.

In the linguistic domain, a handful of studies have investigated the processing of prosodic rhythm in individuals with autism. However, different definitions of "prosodic rhythm" were adopted and operationalised in these experiments, and the findings are inconsistent and difficult to interpret. An example is discussed below. Furthermore, one major criticism of some of these studies concerns the fact that they do not provide verbal intelligence data for the participants, or use any control groups. The majority of these experiments have focused upon assessing productive prosodic skills in individuals with autism, and therefore very little is known about their receptive abilities. These investigations can be divided between those that have examined stress or accent (e.g., Baltaxe, 1984), and those that have assessed phrasing or chunking (e.g., Fine, Bartolucci, Ginsberg, & Szatmari, 1991). In the latter domain, four known studies have investigated such abilities in individuals with autism. Phrasing or chunking refers to the segmentation of utterances for grammatical or semantic meaning, as apparent in the "punctuation" of speech. Chunking is achieved by the use of pause, stress, intonation, and final syllable lengthening (Cruttenden, 1997). In order to illustrate some of the problems with these studies, investigations by Thurber and Tager-Flusberg (1993) and Shriberg, Paul, McSweeny, Klin, Cohen, & Volkmar (2001) will be considered. Thurber and Tager-Flusberg (1993) were interested in examining the production of pauses in story narration by children with autism, children with intellectual impairment, and typically developing children, matched for verbal mental age. Each group included 10 participants, and the mean chronological age of the children with autism was 12 years. The results showed that the children with autism produced a significantly smaller number of non-grammatical pauses (within phrase) than their controls. However, the children with autism did not differ significantly in their use of grammatical pauses (between phrase) when compared to the control children. Non-grammatical pauses generally signal hesitancy or thinking on the part of the speaker (Crystal, 1969), and may also implicate emotional factors (Goldman-Eisler, 1961). As there is evidence to show that typical adults produce more non-grammatical pauses in cognitively demanding tasks compared with less demanding tasks (Goldman-Eisler, 1972), the authors suggested that the story narration task presented substantially reduced communicative and cognitive demands to the children with autism. However, in summary, no deficits in the use of grammatical pauses were observed in the children with autism. By contrast, Shriberg et al. (2001) studied a group of 30 males with high-functioning autism and Asperger syndrome, with a mean age of approximately 21 years. The ages of these participants ranged from 10 to 49 years, and a control group of 30 typical individuals matched for age was included. The results from this study showed that 40 per cent of the participants with high-functioning autism showed inappropriate phrasing of more than 20 per cent of utterances produced, thereby seeming to contradict the findings of Thurber and Tager-Flusberg. However, an inspection of the most frequent types of phrasing errors reveals that they concerned sound, syllable, and word repetitions, thus implicating dysfluency or perhaps word-finding problems. McCann and Peppé (2003) have criticised this study on the grounds that the authors failed to clearly distinguish between prosody and the other linguistic factors in speech. Further, McCann and Peppé observed that, in cases of dysfluency, incomplete phrasing would be expected. Therefore, the findings can be taken as support for the findings of Thurber and Tager-Flusberg, that showed that, when fluent, individuals with autism use phrasing appropriately, but when not, the opposite is true. Further problems with contrasting the findings from these two studies concern the very different groups of participants used, in particular with regard to their ages and the matching procedures used.

Linguistic stress is used to mark an important word in a sentence to contrast with other words, by variation in speech rhythm and relative prominence of syllables. In this domain, more studies have found atypical stress assignment in speech in individuals with autism (McCaleb & Prizant, 1985; Baltaxe, 1984; Baltaxe & Guthrie, 1987; Fosnot & Jun, 1999; Paul, Augustyn, Klin, Volkmar, & Cohen, 2000) than those that have not (Fine et al., 1991). Consequently, it is highly problematic to draw any reliable conclusions about rhythmic abilities in the speech domain in individuals with autism on the basis of the existing literature. Furthermore, linguistic studies might not be particularly relevant to the current study for the reason that the findings of such investigations might have been "confounded" by pragmatic content; the current study aims at establishing rhythmic processing abilities in autism at the perceptual level.

Very few studies have attempted to examine rhythmic processing abilities in music in autism. In a small musical improvisation study of five low-functioning children with autism and intellectually impaired and normal control children, Thaut (1988) found that the rhythmic ability of children with autism did not significantly differ from that of the typically developing control children. Consistent with this, an earlier study by Frith (1972) reported good rhythmic production in children with autism, and she suggested that this finding reflected the propensity to strict temporal rule adherence by such individuals. Thus in summary, on the basis of these studies, it appears that the processing of musical rhythm is preserved in autism.

A previously mentioned investigation that is of particular importance to the current experiment examined tonal and rhythmic processing in both music and speech domains in a family with a congenital developmental language disorder (Alcock et al., 2000). Since this language and speech impairment is characterised by both expressive and receptive language deficits, together with problems with non-verbal oral motor control, the authors investigated the possibility that pitch and temporal processing might also be affected. The findings indicated that whilst none of the affected family members showed any impairments in tasks involving pitch, they showed striking deficits in the perception and production of rhythm. This finding indicates selective dissociation between the processing of tonal and rhythmic information in the affected family members, and suggests that the processing of rhythm might be more vulnerable to disruption than that of tones.

The question to be addressed in this chapter concerns whether the enhanced sensitivity to "musical" aspects of speech in autism, as has been found to be the case for pitch, will manifest within the rhythmic domain of speech. The rationale for isolating rhythm in this study derives from the findings showing pitch and rhythm dissociations (Alcock et al., 2000). It is therefore important to identify any abnormalities in the processing of rhythmic information in speech in autism, as such deficits may impact upon such individuals' language processing difficulties. However, as was discussed earlier, the small number of linguistic studies that have assessed prosodic abilities pertaining to rhythm in individuals with autism are highly contradictory, and constrained by methodological problems. Furthermore, whilst the cited studies have all included pragmatic content, the current study aims at establishing rhythmic processing abilities in autism at the perceptual level, and further, in relation to processing speech for meaning. It will be of particular importance to separate out the abilities at the perceptual and pragmatic levels, as pragmatic impairment is considered to be the most fundamental and universal feature of autism (Tager-Flusberg, 2001b). Speech with and without semantic content will be included, in order to examine how semantic content may influence children's ability to access the perceptual rhythm information in speech. It is difficult to make any specific predictions about these abilities in the speech domain on the basis of the existing literature. By contrast, in the musical domain, studies suggest that children with autism are unimpaired in their perception and production of musical rhythms as compared to control children (Frith, 1972; Thaut, 1988). In the following experiment, children with autism and their matched controls will be presented with short intact speech and pseudo-speech samples, each of which will conform to one of four syllabic rhythm patterns. Furthermore, to assess semantic processing of the intact speech items, a semantic processing measure consisting of control questions will be included. Since decreased semantic bias in language processing in autism is well-documented (e.g., Happé, 1997), the hypothesis stated that children with autism will show equal levels of performance in the intact speech and pseudo-speech conditions. In typical development, however, it is hypothesised that the bias towards processing speech semantically will interfere with the processing of the perceptual levels of speech, resulting in poorer performance in the semantically intact speech condition in the control children.

METHOD

Participants

Twenty-one boys with a formal diagnosis of an autistic spectrum disorder participated in the experiment. Eighteen children were recruited from a specialist educational establishment for children with autistic spectrum disorders, and some of these boys also participated in experiments two, three, and four (see appendix one for details). Three additional children with a diagnosis of an autistic spectrum disorder were recruited from an educational establishment for children with moderate learning difficulties. The children's ages ranged from 8 years, 6 months to 16 years, 3 months (mean 12 years, 10 months, *SD* 2.26). Their verbal ability was assessed using the British Picture Vocabulary Scale (BPVS), and their standardised scores on this measure ranged from 42 to 129 (mean 77, *SD* 20.0), and their raw scores varied from 44 to 140 (mean age equivalent 8 years, 9 months, *SD* 23.86). Seventeen male and four female control children were recruited from four different schools: five children attended a mainstream primary school, four children attended a primary school for children with moderate learning difficulties, three children attended a mainstream secondary school, and nine children attended a secondary school for children with moderate learning difficulties. These children were matched on an individual basis to the children with autism for chronological age and standardised BPVS score. The control children were aged from 8 years, 5 months to 16 years, 1 month (mean 12 years, 11 months, *SD* 2.39). Their standardised scores on the BPVS varied from 44 to 120 (mean 76, *SD* 18.72), and their raw scores ranged from 45 to 123 (mean age equivalent 8 years, 10 months, *SD* 20.23).

Test stimuli

This experiment included two experimental conditions, each including 16 intact speech and 16 pseudo-speech samples. Each stimulus conformed to one of four distinct rhythmic patterns, shown in Figure 5.1. In this representation, each rhythmic pattern was presented on a separate horizontal line. Each black chunk corresponded to a syllable, and the width of the chunk related to the relative length of that syllable.

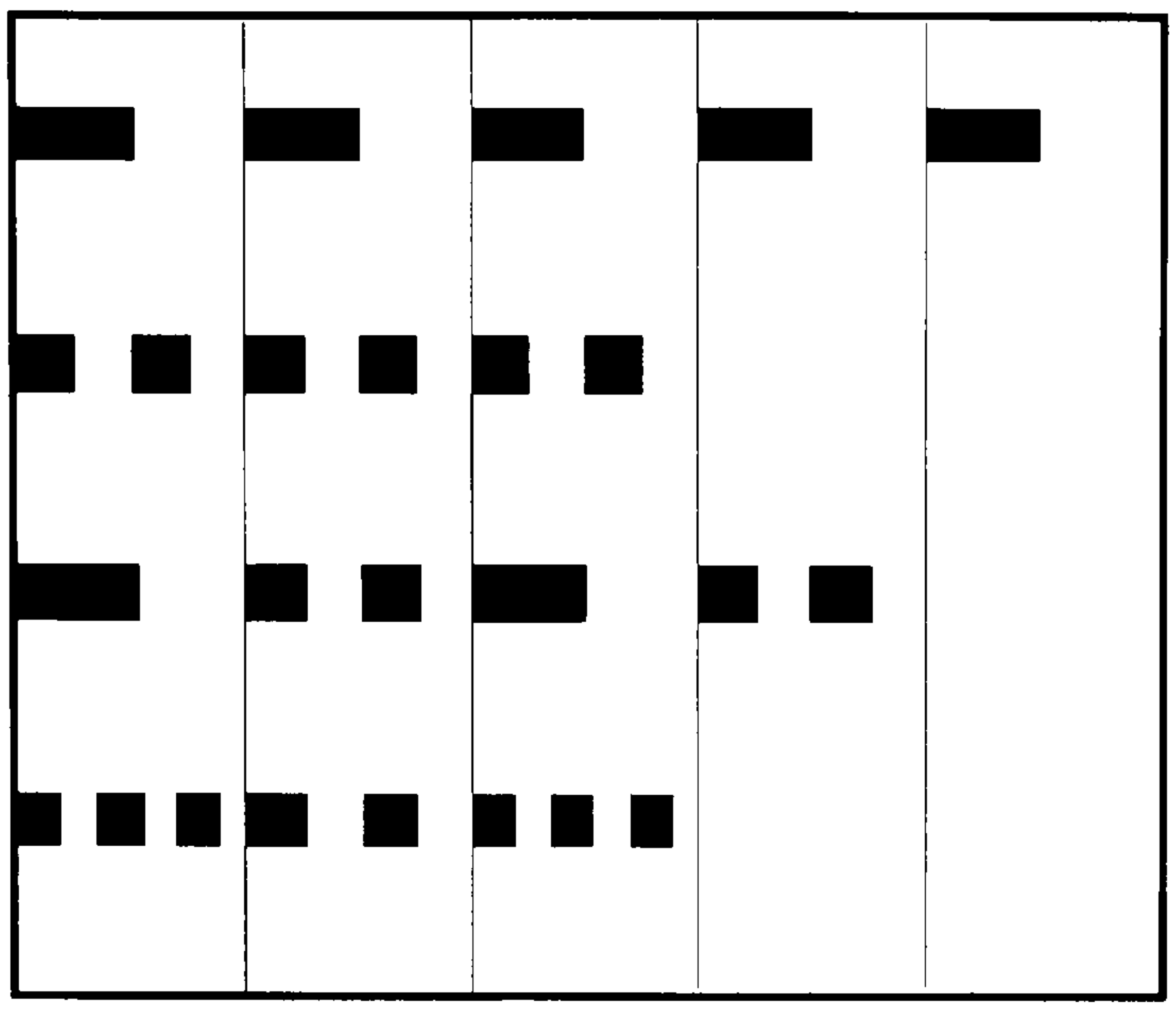
Intact speech stimuli: Sixteen sentences were generated so that they corresponded to one of the four rhythmic patterns, shown in Figure 5.1. Rhythm one comprised five monosyllabic words (e.g., “Let’s go for a walk”), rhythm two comprised of three bi-syllabic words (e.g., “Katie gathers conkers”), rhythm three was constructed of a repeated pattern of a monosyllabic word followed by a bi-syllabic word (e.g., “Your trainers are dirty”), and rhythm four consisted of a tri-syllabic word followed by two monosyllabic words followed by a tri-syllabic word (e.g., “Annabel is from Italy”). These sentences were read by a native English speaking female, and each sentence was recorded directly onto a laptop computer using the GoldWave software package (www.goldwave.com). The sentences were constructed using nouns, verbs, and adjectives that are neutral and that occur frequently in spoken language.

Pseudo-speech stimuli: Sixteen sentences, analogous to those used in the intact speech condition, were generated so that instead of words, the vowels /a/, /e/, /o/, and /u/ were used. Each of the sentences conformed to one of the four rhythmic patterns, shown in Figure 5.1. They were uttered by the same female voice, as in the speech condition. Each rhythmic pattern was read once using the four different vowels. Thus, the rhythmic patterns for the vowel /a/ were as follows: “A A A A A”, “AA AA AA”, “A

AA A AA", and "AAA A A AAA". The order of presentation of the 32 stimuli was randomised in respect to the ordering of the different rhythm patterns and also the stimulus class. The stimuli were presented on a laptop computer, and each auditory sample was followed by a graphic representation of the four rhythmic patterns, shown in Figure 5.1.

Semantic processing measure: Sixteen control questions, based on the semantic information given in each of the sentences in the speech condition, were generated. The semantic questions did not directly name any of the words that appeared in the speech stimuli (with the exception of names), so as to avoid ceiling level performance occurring in the control group. The questions were constructed in such a way that the answer to the question was unambiguous. For example, for the sentence (1) "All Tim's pens are blue", the control question was, "What is Tim's favourite colour?", for the sentence (2) "Stella often dances", the control question was, "Name one of Stella's hobbies", for the sentence (3) "Poppy's learning English", the control question was, "Which language is Poppy hoping to speak well soon?", and for the sentence (4) Emily has a lollipop", the control question was, "What kind of sweets does Emily love?". Only the answers (1) "blue", (2) "dancing/dance/dances", (3) "English", and (4) "lollipop/s" scored one point. As each correct answer scored one point, the maximum score for this condition was 16.

Figure 5.1 Graphic representation of the four syllabic rhythms used in the auditory stimuli



Procedure

Each child was tested individually in a quiet room in their own school. A training phase preceded the experimental testing. The experimenter placed an A4-sized sheet of paper containing the graphic representation of the four rhythmic patterns in front of the child. She explained that the child was going to hear some short sentences and sound groups from the computer, and that in this task, they were said in such a way that they produced four differently sounding patterns. The experimenter read example sentences of each rhythmic pattern to the child, whilst simultaneously following the correct rhythmic pattern with a pen. She then read another four sentences, one by one, each depicting a different rhythmic pattern, and the child was asked to point to the graphic representation that s/he thought best expressed the rhythm in the visual display. If the child's response was inaccurate, the experimenter corrected the child. The child was further told that each sentence told a little story, and now the experimenter was going to ask a simple question relating to the information that was given in the sentence. The child was required to make at least two correct choices in response to the rhythmic patterns before proceeding with the actual testing. If this was not managed on the first attempt, then the same block of four sentences was read again, until this criterion had been satisfied. With regard to the semantic control questions, no such criterion was set due to the well-documented semantic processing impairments in autism. Before starting the experiment, the experimenter told the child that some of the samples were going to be just sounds or noise, but that they would have exactly the same rhythmic patterns as the sentences used in training. In the testing phase, the child was not given any feedback by the experimenter, and the child set the testing pace: although quick responses were encouraged. Following the child's judgement of the rhythmic pattern in response to each of the intact speech stimuli, the experimenter played the sentence again, and asked the control question.

RESULTS

The means and standard deviations for the correct identification of rhythm patterns from both intact speech and pseudo-speech stimuli for the children with autism and the control children are shown in Table 5.1.

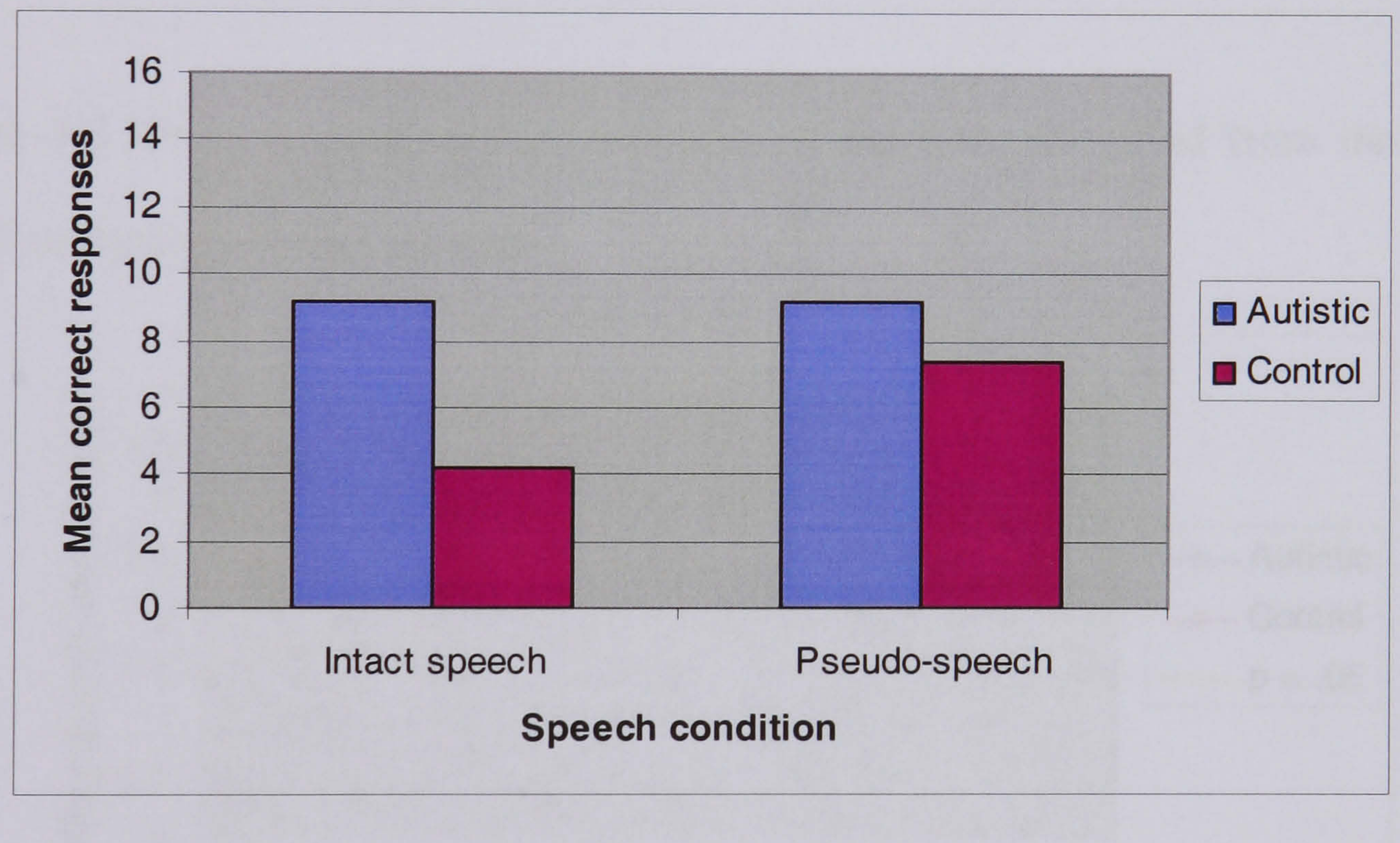
Table 5.1 Means and standard deviations for the correct identification of rhythmic patterns for both the children with autism and their matched controls

	Intact speech condition		**Pseudo-speech condition**	
	Mean	**SD**	**Mean**	**SD**
Autism group (N=21)	9.14	3.67	9.14	3.71
VIQ- and age-matched controls (N=21)	4.19	1.63	7.33	2.69

*Maximum score per condition = 16

The data were subjected to a two-way analysis of variance with speech condition (intact/pseudo) as the within-group factor, and diagnosis (autism/control) as the between-group factor. This analysis revealed a highly significant main effect of speech condition (*F* (1, 40) = 15.56, *p* < .001), with better performance occurring in the pseudo-speech condition overall. Furthermore, the results showed a highly significant main effect of diagnosis (*F* (1, 40) = 15.80, *p* < .001), with children with autism showing higher levels of performance overall, together with a highly significant speech condition by diagnosis interaction (*F* (1, 40) = 15.56, *p* < .001), as illustrated in Figure 5.2.

Figure 5.2 Mean number of correctly identified rhythmic patterns from the intact speech and pseudo-speech samples, for both the children with autism and their matched control children

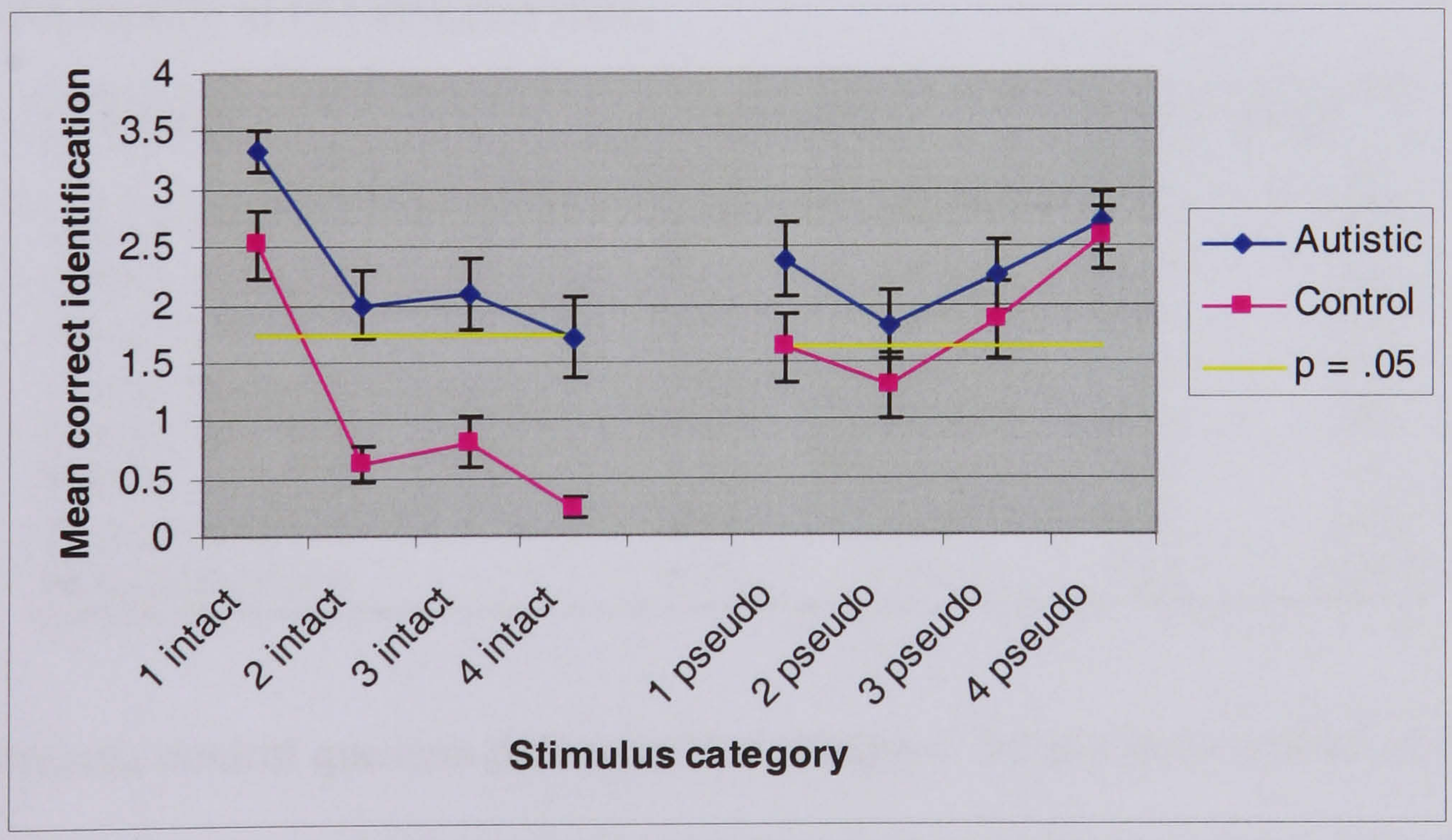


*Maximum score per condition = 16

In order to explore the interaction further, two sets of t-tests were carried out on the data. The independent samples t-tests revealed that the children with autism were significantly better at extracting the rhythmic patterns from the intact speech samples as compared to the controls (*t* (40) = 5.66, *p* < .001), whilst no between-group differences in performance emerged in the pseudo-speech condition (*t* (40) = 1.81, *p* = .08). However, there was a trend towards the children with autism performing better in comparison to the control children. Whilst there was no within-group condition effect for the children with autism (*t* (20) = .00, n.s.), the analysis revealed that the control children were significantly better at extracting the rhythmic patterns from pseudo-speech samples than from intact speech (*t* (20) = -5.36, *p* < .001).

In order to explore the data more fully, patterns of performance across the eight individual stimulus categories were plotted for both groups. Individual mean scores with error bars for each rhythm category for the children with autism and their matched controls are shown in Figure 5.3. The yellow lines denote chance level performance.

Figure 5.3 Mean number of rhythmic patterns correctly identified from the intact speech and pseudo-speech samples



*Maximum score per condition = 4; chance level: *p* = .05;
error bars represent ± 1 standard error

Figure 5.3 shows that the performance profiles of the children with autism and their controls were virtually identical across the experimental conditions, with the difference that the children with autism performed better overall.

As the range of the scores for the intact speech and pseudo-speech conditions was wide for both experimental groups, individual mean scores in the eight stimulus conditions were compared against chance level performance (1), applying one-sample t-tests. These results revealed that the children with autism performed above chance level in all stimuli except in the fourth intact rhythmic pattern, whilst the control children showed above chance level performance in all pseudo-speech conditions but the second. Their performance in the intact speech condition was at chance level except with the first rhythmic pattern. The t-values (20) and their corresponding *p*-values are shown in Table 5.2 below.

Table 5.2 Results of one-sample t-tests

Condition	Autism group		Control group	
	t-value	p	t-value	p
Intact rhythm 1	12.49	<.001	5.26	<.001
Intact rhythm 2	3.24	<.005	-2.36	n.s.
Intact rhythm 3	3.56	<.005	-.89	n.s.
Intact rhythm 4	2.06	n.s.	-8.0	n.s.
Pseudo rhythm 1	4.22	<.001	2.10	.05
Pseudo rhythm 2	2.72	<.015	1.03	n.s.
Pseudo rhythm 3	4.02	.001	2.57	<.02
Pseudo rhythm 4	6.38	<.001	5.77	<.001

The semantic control question data were then analysed. Means and standard deviations for the children with autism and their matched controls are shown in Table 5.3 below.

Table 5.3 Means and standard deviations for the semantic processing score for both the children with autism and their controls

	Semantic processing score	
	Mean	**SD**
Autism group (N=21)	11.52	4.82
VIQ- and age-matched controls (N=21)	15.00	1.61

*Maximum score = 16

In order to examine differences in the semantic processing of the intact speech samples between the children with autism and their controls, an independent samples t-test was carried out on the data. This analysis revealed that the control children were significantly better at extracting the meaning of the sentences, compared with the children with autism (t (40) = -3.13, $p < .005$). Inspection of the standard deviations shows that this value is large for the children with autism (4.82 versus 1.61 for controls); in fact their scores ranged from the minimum of zero to the maximum of 16. This finding will be discussed further.

In order to investigate whether overall performance in the rhythm task might improve with age and intelligence, correlations were carried out between age, psychometric, and experimental data. For the children with autism, a significant positive correlation emerged between performance levels in the intact speech and pseudo-speech conditions ($r = .78$, $p < .001$), and between the semantic processing score and verbal intelligence ($r = .47$, $p < .05$). All other correlations failed to reach significance. For the children in the control group, a significant positive correlation emerged between age and semantic processing score ($r = .58$, $p < .01$), and between performance in the pseudo-speech condition and performance in the semantic processing measure ($r = .48, p < .05$). This finding will be discussed further. All other correlations failed to reach significance.

Finally, as the hypothesis of this experiment was formulated to test the core predictions of the weak central coherence (WCC) theory (Frith, 1989a; Happé, 1999), and the theory of enhanced perceptual functioning (EPF) (Mottron & Burack, 2001), predicting that individuals with autism would process the perceptual levels of speech at the expense of semantic processing, the individual children's perceptual versus semantic processing patterns were considered within the data from the autism group. Table 5.4 displays the proportion of children (in percentages) in the sample exhibiting four distinct processing styles. These categories were: children with high perceptual (65% correct or above) and high semantic ability (69% correct or above); children with high perceptual and low semantic ability (33% correct or below); children with high semantic and low perceptual ability (33% correct or below); and children with low perceptual and low semantic ability.

Table 5.4 Proportions of children (in %) in the autism sample falling within each of the four distinct processing categories

	High perceptual and high semantic ability	High perceptual and low semantic ability	High semantic and low perceptual ability	Low perceptual and low semantic ability
% of children in the sample	38	14	29	14

Table 5.4 shows that 52 per cent of the children in the autism sample showed enhanced perceptual processing, whilst 28 per cent showed low semantic processing ability. However, only 14 per cent of the children in the sample exhibited a processing style that conformed to the predictions of the WCC and EPF theories. This will be discussed

further below. The remaining five per cent of the children in the sample did not conform to any of the processing styles described above.

DISCUSSION

As little is known about rhythmic processing abilities in autism, and since evidence from individuals with congenital language disorder shows that the processing of pitch and rhythm can selectively dissociate (Alcock et al., 2000), this study was aimed at ruling out any such deficits in autism. The findings from this experiment showed firstly, that children with autism were significantly better at extracting rhythmic patterns from semantically intact speech stimuli compared with their age- and intelligence matched controls. Secondly, no between-group differences in the ability to process rhythm patterns in pseudo-speech stimuli emerged. Thus, these findings established that rhythmic processing abilities are intact in autism, and thus are consistent with results obtained in the musical domain (Frith, 1972; Thaut, 1988). Another important finding showed that the children with autism were significantly poorer than their matched controls at processing the intact speech items for meaning. It was also found that in autism, semantic competence was associated with verbal intelligence. Thus, these findings lent support to the hypothesis that the reduced semantic bias in speech processing in autism results in such individuals being equally able to process perceptual level information in stimuli with and without semantic content. The data exploring above chance level performance supported this view, and showed that whilst the control children performed above chance in three pseudo-speech rhythm patterns and none of the intact ones, the children with autism performed above chance with all stimuli, except for one of the intact rhythm patterns. Further support for this prediction was derived from correlational analysis, indicating that for the control children, good performance in the pseudo-speech condition was associated with semantic processing competence. Thus, the semantic bias in the control children meant that they were only able to process rhythmic information in stimuli that had no semantic content, suggesting that semantic aspects of the stimuli did indeed hamper these children's ability to process the perceptual level of speech. Furthermore, for the children with autism, performance in the intact speech and pseudo-speech conditions correlated with each other. As no such correlation was found for the control children, these findings suggested that the children with autism were significantly less influenced by the semantic content of the intact stimuli, and that their rhythmic processing abilities were significantly less dependent on the stimulus class than was the case for the control children.

The finding that the children with autism and their controls did not show significantly different levels of performance in the pseudo-speech condition suggests that children with autism do not show enhanced perceptual processing. Rather, this study showed that one consequence of the reduced semantic bias in autism (reported in chapter three) is increased access to perceptual information in speech stimuli. Whilst the group analysis of the current findings provides support for the hypothesised perceptual versus semantic "trade-off" in speech processing in autism, an analysis of the individual children's data in the autism sample showed that the proportion of children who showed high perceptual ability together with compromised semantic processing was very small, only constituting 14 per cent of the sample. Furthermore, an important finding was that 38 per cent of the children with autism showed enhanced perceptual processing alongside good semantic processing ability. Taken together with similar findings from experiment two, the results suggest that enhanced perceptual processing and higher-level linguistic abilities may be associated with each other in some children. Thus, these results challenge the predictions of the weak central coherence (WCC) theory (Frith, 1989a; Happé, 1999) and the theory of enhanced perceptual functioning (EPF) (Mottron & Burack, 2001), as both would assume, firstly, that perceptual level processing would be enhanced, and secondly, that perceptual processing would occur at the expense of processing speech for meaning in autism. The current findings are in line with those reported in experiment four, which also failed to find evidence of enhanced perceptual processing in autism. Thus, again, the results from experiment five may be best conceptualised within the framework of the enactive mind model (Klin, Jones, Schultz, & Volkmar, 2003), where the substantially reduced early salience of socially relevant stimuli is assumed to result in enhanced specialisations being formed in physical rather than in social stimuli. In the present study, children with autism only exhibited superior performance to controls in the intact speech condition; thus, an abnormal modularisation explanation can better accommodate the current pattern of findings than the theories that are based upon an enhanced perceptual functioning (i.e., the WCC and EPF accounts) explanation of autism.

As the current study and experiments one and two employed the same paradigm, only differing on the type of perceptual information (pitch/rhythm) incorporated, it is interesting to compare the patterns of results obtained from these studies with each other. Whilst experiments one and two found evidence of enhanced perceptual processing in autism, the current study did not. Furthermore, although both experiments two and five found reduced semantic bias in children with autism, only the present study found support for the hypothesis that, in typical development, the typical bias towards semantic processing interferes with the perceptual processing of speech, as the control children did not show worse performance in the semantically intact speech condition relative to other conditions in experiments one and two. Thus, these findings are puzzling as they suggest that semantic information only influenced the control children's ability to process rhythmic patterns in speech, whilst the processing of pitch was unaffected. This finding suggests that the processing of pitch and rhythm information is qualitatively different.

How could the above pattern of seemingly contradictory findings be explained? One possibility is to consider the relative importance of pitch and rhythmic information in speech. According to Lieberman (1960), pitch is the main component, and the most fundamental cue to prosody. Developmental studies with infants have suggested that their auditory discrimination is largely based upon melodic contour; that is, the direction of pitch changes (Trehub, Bull, & Thorpe, 1984; Trehub, Thorpe, & Morrongiello, 1987). Indeed, Trehub (2001) argues strongly for the view that pitch contour is the most salient feature of melodies for infants. However, musical studies have also shown that infants can discriminate between pitch sequences with identical pitches but different rhythmic arrangements (Trehub & Thorpe, 1989; Demany, McKenzie, & Vurpillot, 1977), suggesting that rhythmic processing might also be relatively sophisticated at birth. As prosody comprises pitch and rhythmic variations, further support for the presence of sophisticated rhythmic abilities in infancy derives from studies showing that neonates can discriminate between their native language and other languages on the basis of prosodic cues alone (e.g., Mehler, Jusczyk, Lambertz, Halsted, Bertoncini, & Amiel-Tison, 1988), and between familiar and unfamiliar stories (DeCasper & Spence, 1986). Consequently, it has been suggested that infants are specifically attuned to pitch contours and rhythmic patterns in speech. The findings from experiments one, two, and three indicated that children with autism showed a particularly heightened sensitivity to pitch information in speech and speech-like stimuli, compared to their matched controls. In contrast, the findings from the present study indicated that the control children were equally good at processing rhythmic patterns as their autistic counterparts when semantic processing demands were reduced; thus, the perceptual differences between children with autism and their controls appear to be more pronounced with pitch than is the case of rhythmic processing.

Whilst pitch can be extracted from a single sound, rhythm requires gestalt representation: it can only exist if a series of sounds are presented. Thus, pitch exists independently of any external reference, whereas the perception of rhythms is always in relation to other, adjacent sounds. In other words, pitch is detail and a purely perceptual parameter, whilst rhythm is a pattern of sounds, with the perception of such thereby involving pattern recognition mechanisms. Pitch and rhythm are similar in that they are both characterised by a temporal periodicity. However, whereas the time base (or wavelength, λ) in pitch is too short for the human brain to perceive (300 microseconds $\leq \lambda \leq$ 3milliseconds being typical of human speech), making its perception a purely sensory issue, the period associated with rhythmic variations is significantly longer (250-350 milliseconds for the fastest music and more typically on the order of seconds or even tens of seconds for other stimuli, including human speech), thereby enabling the human perceptual system to process the rhythmic repetition. The key point here is that rhythm is only meaningful at the cognitive level. In the light of the findings from experiment two, it might be speculated that for typically developing individuals, pitches that are "trivial", or not directly linguistically or melodically functional, are significantly more difficult to detect than they are for individuals with autism. The results from this study are discussed further in chapter six, in the context of findings from prosodic rhythm measures that involved semantic and pragmatic meaning.

Chapter Six

Comprehension of Speech Prosody by Children with Autism

Summary: The question asked in this chapter concerned how children with autism, who in previously presented experiments showed enhanced processing of pitch and rhythm in speech, would understand the linguistic, global function of such prosodic cues in their natural communicative context. Children with autism and their matched controls were assessed on the Profiling Elements of Prosodic Systems in Children (PEPS-C; Version 1.6) test battery, (Peppé, McCann, & Gibbon, 2003), to obtain non-experimental background data on their prosodic abilities. The findings showed that the children with autism had significantly poorer receptive and expressive prosodic abilities compared to their matched control children.

INTRODUCTION

Language disabilities characteristic of autism often encompass prosodic abnormalities (see McCann & Peppé, 2003, for a recent review). As the findings from the previously reported experiments have indicated that children with autism show an unusual pattern of pitch and rhythm processing in speech, it was felt necessary to assess the children's prosodic abilities formally, in order to gain a more complete picture of their processing abilities. Furthermore, findings from experiments four and five suggested that the atypical perceptual processing in autism is more social in origin than was perhaps previously thought (cf. Frith, 1989a; Mottron & Burack, 2001). Even Kanner's (1943) earliest description of autism made numerous references to the unusual prosodic qualities of the children's speech. Such observations include "parroting" modes of speech, to the extent of that some of the children imitated the exact intonation of heard utterances, exhibited literal repetition of questions, and sometimes produced utterances with the same vocal inflection repeatedly. Furthermore, some children with otherwise reasonably developed speech were noted to have "defective" articulation; others spoke with a "peculiarly un-modulated" and hoarse voice, and used generally "odd" intonation. Another prominent observation in Kanner's account of the speech of the children was a reduced tendency to ask questions. In Kanner's view, the production of utterances was related to the working memory capacity since he noted that some echolalic children only repeated back the end portion of sentences if they were lengthy.

Although prosodic abnormalities, such as those described above, are often reported for individuals with autism, the literature does not specify the exact nature of the abnormality (McCann & Peppé, 2003). Prosodic terminology is used erratically, with prosodic function not always being distinguished from its form. Whereas function refers to the pragmatic and semantic meaning of prosody, form is the means (pitch / fundamental frequency-, loudness / intensity-, pause / silence-, speech rate and rhythm variations) by which prosodic effect is produced (Crystal, 1969). For instance, the term “stress” can refer to the assigning of focus on a linguistic component (“I like MATHS” versus “I LIKE maths”) and also to the form. This distinction is important as prosody carries both linguistic and paralinguistic functions. Thus, in order to elucidate the ways in which prosodic difficulties might contribute to the language impairment associated with autism, the PEPS-C test battery was administered to the children with autism and their matched controls. This test allows the assessment of prosodic abnormalities at the “form” level (i.e., an inability to perceive pitch-mediated differences) and at the “function” level (e.g., an inability to appreciate the pragmatic function of stress). As the experiments reported earlier in this thesis have established that children with autism show enhanced sensitivity to the perceptual properties of speech, it is anticipated that their impairments will reside largely at the function level. Furthermore, the language impairment present in autism includes pragmatic (and semantic) difficulties, and it is therefore predicted that children with autism will show worse performance in the subtests involving pragmatic function than in those only involving the perception of prosodic form.

BACKGROUND INFORMATION ABOUT THE PEPS-C TEST

The children’s version of the PEPS-C test has been standardised on 120 Southern British English children. This data showed that prosodic competencies develop unevenly in children. Adults have been shown to score at or near ceiling in this test. The assessment follows a psycholinguistic framework (Wells & Peppé, 2001), whereby both receptive (input) and expressive (output) abilities are measured in analogous tasks. The tasks are further divided into form (bottom-up processing with no meaning involved) and function (top-down processing involving pragmatic meaning). The purpose of the receptive form tasks is to assess whether the participants possess the underlying skills required for understanding prosody; namely, the auditory abilities needed for discriminating between different types of prosody and/or intonation. The expressive form tasks have been designed to assess an individual's ability to produce the different types of intonation and prosody. Thus, the abilities needed to complete the form tasks are thought to be a prerequisite for the abilities measured by the function subtests. The assessment is computerised, and records participants' responses into sound and text files. All expressive (output) tasks are subjected to double-rating. The test includes 12 subtests measuring perception, comprehension, repetition, and meaningful production, divided equally between receptive and expressive tasks. Each subtest includes two example items, two practice items, and 16 test items. Only the test items count towards the participant's total score; thus, the total maximum test score is 192 (96 for both receptive and expressive domains). The subtests are as follows:

(1) Turn-end type input (function): This task assesses the ability to understand questioning versus declarative intonation over single word "conversational turns". The stimuli consist of food words which are presented with opposing intonation either as offering ("would you like some?") or reading ("this is what I see in the book."). The participant's task is to match auditory to visual stimuli by clicking either side of the computer screen with the mouse pointer. The response slide has a picture of a boy holding the food item in question on a plate and a question mark on the left hand side of the screen, and a picture of a boy looking at a picture of the food item in question in a book on the right hand side.

(2) Turn-end type output (function): The participant's task is to make offering and declaring pronunciations of food items as prompted by pictures. For example, the screen may show a boy holding a carrot on a plate and a question mark (offering), or a picture of a boy looking at a picture of a carrot in a book (declaring). The experimenter is blind to the screen and rates the responses as questioning, declaring, or ambiguous, on the basis of intonation, using a customised keypad. The participant's verbal responses are recorded by the computer for double-rating.

(3) Affect input (function): This task assesses the ability to understand affective or attitudinal meaning conveyed by intonation. The stimuli are again single-word food items expressed as strong liking or disliking (reservation). Each auditory sample is followed by a screen depicting a happy face on the left, and a sad face on the right hand side of the screen. The participant's task is to click on the matching face with the mouse pointer.

(4) Affect output (function): The participant's task is to express like and dislike to single-word food items. Pictures of food appear on the screen one by one, and the experimenter simultaneously tries to guess whether the participant likes the food, by rating the responses blindly using the keypad. The participant indicates their intended affect after the experimenter's judgement by clicking on a happy or sad face with the mouse pointer.

(5) Intonation input (form): This subtest assesses the ability to perceive differences in intonation. The stimuli are pairs of same and different short laryngographic sounds, and the participant's task is to indicate their responses by clicking on the appropriate side of the computer screen (same versus different) with the mouse pointer.

(6) Intonation output (form): This task assesses the ability to imitate different forms of intonation. The stimuli are single words pronounced as questions, statements, or with affective intonation expressing liking or reservation. For example, the participant may be required to imitate a voice uttering "carrot" as a question with a rising intonation, or the word "bread" with a voice expressing dislike. The experimenter rates the participant's responses simultaneously as a "good response", "fair response" or "poor response".

(7) Chunking input (function): This subtest assesses the ability to understand syntactically ambiguous sentences disambiguated by prosody. "Chunking" refers to phrasing or boundary-marking of a sentence into units or "chunks" for grammatical, semantic or pragmatic purposes. The stimuli employ minor phrase boundaries which can be used to differentiate items in a list. Some of the phrases use colour combinations, e.g., "pink, and black and green socks" (signalling a boundary after the first item), or "pink and black, and green socks" (signalling a boundary after the second item). Other stimuli utterances consist of single- and compound food items, such as "fish, fingers, and fruit" versus "fish-fingers and fruit". The participant is required to click on a picture on the screen that depicts the utterance using the mouse pointer.

(8) Chunking output (function): Here, the participant is asked to produce syntactically ambiguous phrases unambiguously, by telling the experimenter what he or she sees on the computer screen. The targeted phrases are the same to those that appeared in the input task. The experimenter rates the responses blindly, by indicating whether the participant marked the boundary after the first or second word, or whether it was ambiguous.

(9) Focus input (function): This test measures the ability to perceive contrastive stress or focus. Focus refers to the speaker's use of emphasis to make a distinction between the most important word in the phrase and those of lesser importance. In this task, the participant is told that the person on the computer went to buy some socks, but forgot to buy one colour, and it is the participant's task to indicate the colour (between two colours) that was forgotten. Examples of sentences are, "I wanted BLUE and black socks" versus "I wanted blue and BLACK socks". The participant responds by clicking on the appropriate colour patch on the screen with the mouse pointer.

(10) Focus output (function): Here, the participant is asked to produce contrastive stress. The scenario is that of a football match between cows and sheep, which are of different colour! The participant's task is to correct a commentator who incorrectly states either the animal or the colour of the animal which has the ball. Pictures of animals appear on the screen one by one, accompanied by a commentary. The participant is requested to correct the observation by emphasising the correct colour or animal. The experimenter rates the responses blindly by indicating whether the participant used contrastive stress on the colour (the first word of noun phrase), on the animal (the second word of noun phrase), or whether the stress was ambiguous.

(11) Prosody input (form): This task assesses the ability to perceive prosodic differences. The design of the task is identical to the subtest (5), intonation input, but here the laryngographic utterances are longer.

(12) Prosody output (form): This subtest uses the format of the subtest (6), but here the participant is asked to imitate phrases rather than words. The phrases use chunking and contrastive stress.

METHOD

Participants

Twenty-one children with a diagnosis of an autistic spectrum disorder, who participated in experiment two, were tested. Their psychometric (standardised BPVS and Raven's scores) and age data are shown in Table 6.1 below. These children's raw scores on the BPVS ranged from 56 to 142 (mean age equivalent 8 years, 9 months, *SD* 24.05).

Twelve male and eight female control children were tested. An extra child was tested, whose autistic counterpart was subsequently not available. However, her data were included in the data analysis. Twelve children attended a mainstream primary school, three children attended a primary school for children with moderate learning difficulties, and seven children attended a secondary school for children with moderate learning difficulties. These children were matched in pair-wise fashion to the children with autism, on the basis of chronological age and their standardised score on the British Picture Vocabulary Scale. These children's raw scores on the BPVS ranged from 66 to 129 (mean age equivalent 9 years, 4 months, *SD* 20.09). The Raven's Progressive Matrices were also administered and the means and ranges of standardised scores showed no significant difference between the children with autism and their age- and verbal intelligence matched controls. The mean MA for the children with autism on the Raven's Progressive Matrices was 11 years, 2 months, and the mean MA for the control children was 10 years, 7 months. The children's psychometric and age data are shown in Table 6.1.

Table 6.1 Psychometric and age data for the children with autism and their matched control children

Group	Age			BPVS standardised score			Raven's standardised score		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Children with autism (N=21)	12y7m*	2.50	7y;8m-16y;9m	83*	20.36	42-135	89*	14.08	66-119
VIQ- and age-matched controls (N=22)	12y9m*	2.19	9y;4m-16y;3m	87*	22.36	44-124	83*	17.19	61-121

*No significant difference between groups for age (*t* (41) = .66, n.s.), BPVS (*t* (41) = -.66, n.s.) or Raven's (*t* (41) = .18, n.s.)

Procedure

Each child was tested on an individual basis in a quiet room in their own school. As the test takes between 40 minutes to an hour to administer, it was in one case necessary to split the testing between two separate days. All other children completed the test in one sitting. The child was seated in front of a laptop computer, within easy reach of the computer mouse. Where possible, the experimenter sat diagonal to the child, in such a way that both could see the computer screen, except as discussed below, with the experimenter having easy access to the customised keypad used for rating the participant's output responses. The child was told by the experimenter that s/he would be given a series of speech tasks on the computer. Prior to administering the subtests, two preliminary tasks were carried out: a vocabulary check ensured that the child was familiar with the items that would appear in the subtests. Here, pictures appear one by one on the screen, and the child was asked to name each item. The experimenter explained to the child that some of the items may be unfamiliar, and helped the child where necessary. The second preliminary task was a same/different concept check, which ensured that the child was familiar with such concepts. Here, the first screen depicts two identical red circles, with the word "same" written underneath, and the child was asked to state what he or she notices about the two circles. The second screen depicts a red circle and a green square, with the word "different" spelt underneath, and again the child was asked to comment on them. The subtests were administered in the order listed above where possible. No feedback was given on the task performance, except for positive reinforcement. However, some of the children with autism were unable to complete the output tasks, due to either insufficient expressive language ability, or unwillingness to speak. For the output tasks, the experimenter avoided looking at the computer screen, as is recommended by the user manual. In cases where a child had immature motor skills, the experimenter manoeuvred the mouse pointer on the child's behalf.

RESULTS FROM PEPS-C INPUT TASKS

The means and standard deviations for performance scores in the six PEPS-C receptive subtests, and for the total input score, for the children with autism and their age- and intelligence matched control children are shown in Table 6.2.

Table 6.2 Means and standard deviations for the receptive subtest and total scores for both the children with autism and their age- and intelligence matched controls

PEPS-C subtest	Autism group		VIQ- and age matched controls	
	Mean	SD	Mean	SD
Affect input (function)	11.57**	3.59	13.91**	2.41
Chunking input (function)	10.95**	2.92	12.77**	2.76
Focus input (function)	10.71	2.76	10.91	3.02
Intonation (form)	12.67	3.54	14.00	2.55
Prosody (form)	10.95**	4.19	13.59**	2.81
Turn-end type (function)	11.05	3.98	12.50	3.66
Total input score	67.90**	15.79	77.69**	13.85

*Maximum score per subtest = 16; maximum total score = 96

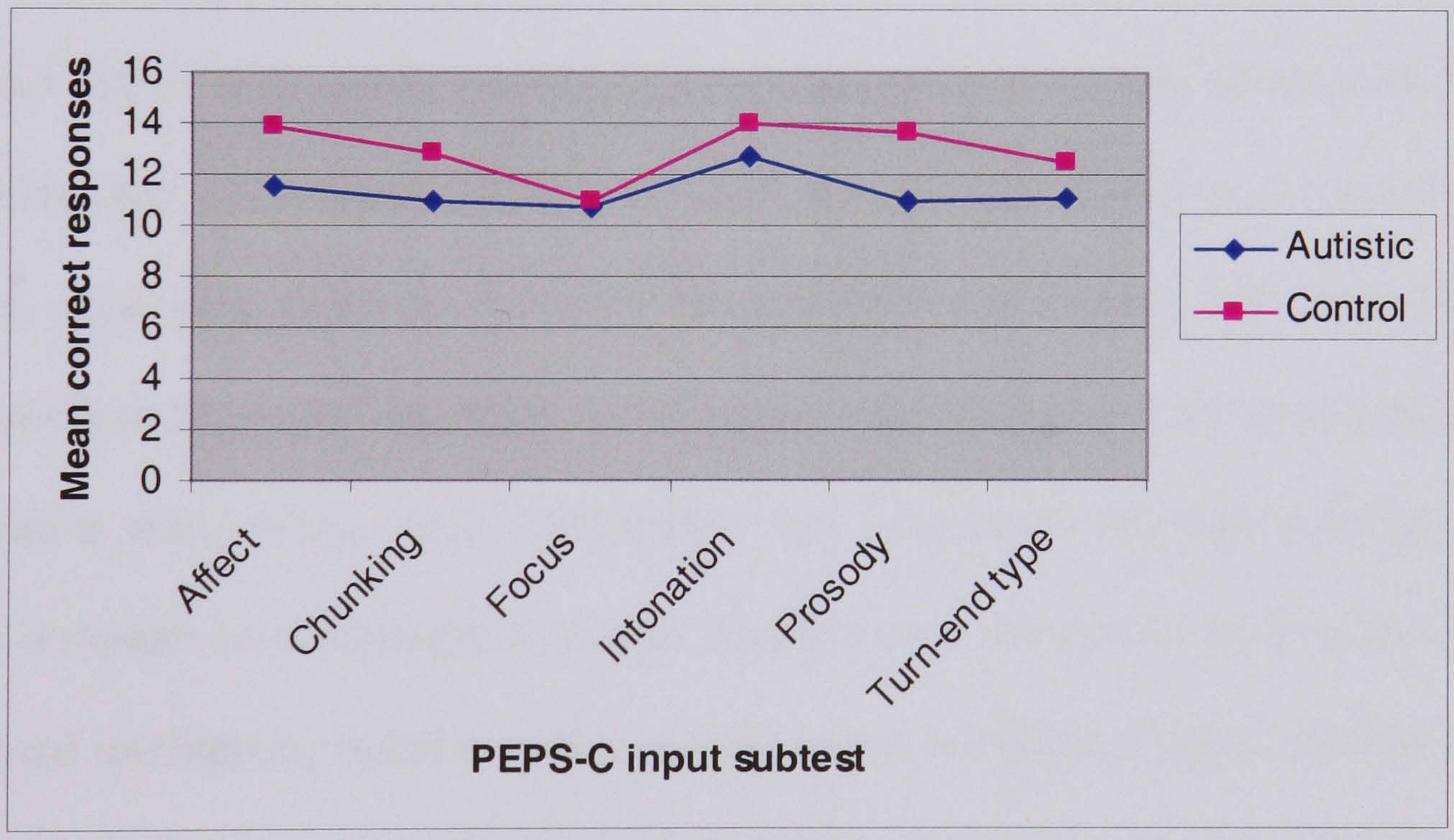
**Between-groups difference p .05

In order to examine differences in performance across the six subtests and the total score between the children with autism and their matched controls, independent samples t-tests were carried out on the data. This analysis revealed that the control children performed at a significantly higher level compared to the children with autism in three subtests: (1) affect (t (41) = -2.53, $p < .02$), indicating that the control children were significantly better at understanding affective connotations (liking and disliking) in speech compared to the children with autism. This task assessed prosodic function, requiring top-down processing for pragmatic meaning. (2) Chunking (t (41) = -2.10, $p < .05$), showing that children with autism were significantly poorer at disambiguating the meaning of utterances on the basis of phrase boundaries than their matched controls. This subtest again assessed prosodic function, and was perhaps the most semantically loaded test in the battery. Finally, (3) prosody (t (41) = -2.44, $p < .02$), indicating that the control children were significantly better at recognising prosodic form differences in pairs of laryngographic sounds at the phrasal level compared to their autistic counterparts. This finding is surprising as this measure was purely perceptual, and included no phonological content. However, a large standard deviation for this subtest for the children with autism (4.19 versus 2.81 for the control children) suggests that this ability was highly varied.

There were no significant between-group differences in performance in the focus (t (41) = -.22, n.s.), intonation (t (41) = -1.42, n.s.), and turn-end type (t (41) = -1.25, n.s.) subtests. Thus, both groups of children were equally good at perceiving intonational variations in short laryngographic sounds (intonation), understanding contrastive stress (focus), and understanding questioning and declaring utterances at the single-word level (turn-end type). The latter two results were surprising as both of the subtests required processing for meaning. However, an inspection of the means for the focus subtest, shown in Table 6.2, reveals that both groups of children achieved their lowest scores in this measure. Analysis of the total input score data indicated that overall, the children with autism showed significantly poorer understanding of prosody than their controls (t $(41) = -2.16, p < .05$). These findings will be discussed further in the discussion sections of this chapter.

The pattern of responding across the six receptive prosody subtests for the children with autism and for their matched control children is illustrated in Figure 6.1.

Figure 6.1 Mean scores in the six input subtests for the children with autism and their matched controls



*Maximum score per subtest = 16

Figure 6.1 shows that both groups of children exhibited very similar patterns of performance across the six receptive subtests.

Correlations were carried out between age, psychometric and subtest data for the children with autism and their controls. A summary of this analysis is shown below in Table 6.3.

Table 6.3 Relationship between age-, psychometric-, and input subtest data for the children with autism (and their control children in parentheses)

	BPVS	Raven	Affect	Chunking	Focus	Intonation	Prosody	Turn-end type
Age	n/a	n/a	.44*(-.43*)	.26(-.25)	.42(-.27)	-.21(-.04)	.20(-.11)	.19(-.10)
BPVS		.37(.78**)	.07(.50**)	.29(.47*)	.03(.64**)	.56**(.43*)	.50*(.50*)	.42(.61**)
Raven's			-.14(.44*)	.13(.55**)	-.01(.72**)	.47(.52*)	.35(.49*)	.29(.77**)
Affect				.37(.71**)	.45*(.43*)	-.01(.28)	.38(.65**)	.36(.44*)
Chunking					.61**(.36)	.28(.51*)	.43(.60**)	.65**(.61)
Focus						.16(.58**)	.53*(.54*)	.52*(.74**)
Intonation							.79**(.73**)	.64** (.68**)
Prosody								.83**(.67**)

$*p$ .05; $**p$ .01

Table 6.3 shows that verbal intelligence correlated positively with all subtests for the control children, whilst such relationship only emerged with the intonation and prosody subtests, measuring prosodic form, for the children with autism. The form subtests assessed the auditory abilities required for perceiving prosody, and it is puzzling that for the children with autism, verbal intelligence was associated with such abilities, as the stimuli included no phonological content. Furthermore, the results showed that whilst non-verbal intelligence failed to correlate with any of the PEPS-C input subtests for the children with autism, it correlated positively with all subtests for the children in the control group. The finding that non-verbal intelligence correlated most closely with the subtests that achieved the lowest mean performance scores (focus, chunking, and turn-end type) for the controls, suggests that general intellectual abilities were important for understanding these aspects of prosody in these children. Verbal and non-verbal intelligence correlated strongly with each other for the children in the control group, suggesting that these children possessed relatively even intellectual abilities within the verbal and non-verbal domains.

The subtest assessing the ability to perceive affective connotations in voice correlated positively with performance in all subtests except that of intonation for the children in the control group. By contrast, for the children with autism, this subtest correlated only with the focus subtest, suggesting that the ability to perceive vocally expressed affect was more fundamental to prosodic abilities in the control children than in those with autism.

For the subtests assessing the ability to perceive prosodic form, a strong positive relationship emerged between the ability to recognise such differences in short and long laryngographic utterances (intonation and prosody subtests) for both groups of children. Although the results from the t-test analysis showed that the control children performed significantly better in the prosody subtest (involving longer stimuli) compared to the children with autism, the positive correlation for the children with autism suggests a general ability in a subgroup of these children to perceive intonation form, regardless of prosody type and stimulus length. As the prosody subtest assessed the ability to perceive prosodic differences produced by contrastive stress and chunking, it is interesting to note that for the control children, performance in the prosody subtest correlated positively with both the focus and chunking subtests, suggesting corresponding abilities in the form and function domains. For the children with autism, performance in the prosody subtest correlated positively with performance in the focus subtest only, suggesting that children with autism were competent at perceiving and comprehending the prosodic effects produced by focus.

A related subtest, also assessing the ability to perceive intonation, is that of turn-end type. A strong positive relationship emerged between this and the intonation and prosody subtests, for children with autism and their controls. This finding is surprising as the intonation and prosody subtests did not demand processing for meaning, whilst the turn-end type subtest did. It thus appears that the children, who were good at perceiving variations in intonation, were also aware of its linguistic function. However, as the intonation subtest further assessed the ability to perceive affective intonation, the finding that the intonation subtest did not correlate with the affect subtest results suggests a discrepancy between the form and function levels for this aspect of prosody.

The subtests assessing chunking and focus are those that are mostly concerned with prosodic rhythm. Furthermore, both of these measures involve processing for semantic and pragmatic meaning. For the children with autism, a strong positive relationship emerged between the ability to perceive minor phrase boundaries (chunking) and contrastive stress (focus). Interestingly, no such relationship was apparent for the control children.

Overall, as is illustrated in Table 6.3, a higher number of between subtest correlations (12 out of possible 15) were evident for the children in the control group compared with the children with autism (eight out of 15), indicating a more coherent prosodic understanding in the controls. For the children with autism, it was found that a good understanding of questioning versus declaring intonation (turn-end type; three strong correlations (p .01) and a weaker one (p .05) with other subtests), followed by focus (one strong correlation and three weaker ones) were central to general receptive prosodic ability. For the control children, the ability to perceive prosodic form at the phrasal level (prosody subtest), followed by the ability to understand questioning and declaring intonation (turn-end type subtest), were found to be most critical for general receptive prosodic competence.

Finally, correlations were carried out between the total receptive PEPS-C prosody score, reported in Table 6.2, and the children's age, and psychometric data, shown in Table 6.1. This analysis showed that for the children with autism, verbal intelligence correlated positively with the total receptive PEPS-C score ($r = .49, p < .05$), suggesting that verbal ability, as measured by the BPVS, was important for overall receptive prosodic competence. For the control children, a significant positive correlation also emerged between verbal intelligence and the total receptive prosody score ($r = .66, p = .001$), suggesting that for both groups of children, verbal intelligence was associated with receptive prosodic abilities. A further correlation for the control children emerged between the receptive prosody score and the level of non-verbal intelligence ($r = .81, p < .001$), suggesting that non-verbal intellectual ability was even more important for prosodic understanding than the level of verbal ability as measured by the BPVS. The findings described in this section will be discussed further in the discussion sections of this chapter.

In the following section, the observed pattern of spared abilities and deficits in prosodic processing in the children with autism will be discussed in the context of the experimental findings reported earlier in this thesis.

DISCUSSION: RELATIONSHIP BETWEEN THE PEPS-C RECEPTIVE PROSODY SUBTESTS AND EXPERIMENTAL DATA

Further correlations were carried out between the experimental data reported in this thesis, and the PEPS-C input subtest data that assessed the corresponding linguistic functions of the perceptual tasks, for the children with autism and their matched controls. The rationale was to relate the children's perceptual processing abilities regarding the prosodic components of pitch and rhythm to the children's understanding of their corresponding global linguistic functions in speech. The results of this analysis, together with the relevance of the findings from each subtest to the experimental data, are discussed under appropriate PEPS-C subtest headings below.

Affect input

The findings from the affect subtest, indicating significantly worse performance in the autism group compared to the controls, are not discussed in the context of experimental data reported in this thesis as none have involved affect. It has been suggested that positive emotion is usually uttered with a wider and higher pitch range than negative emotion (Couper-Cuhlen, 1986). This subtest had obvious implications for meta-representational abilities, as liking and disliking are mental state terms, and thus the understanding of the speaker's prosody was directly related to the children's ability to understand the speaker's mental state. Consistent with the current findings, previous studies have found that individuals with autism show difficulties with inferring the speaker's mental state or mood from a voice (e.g., Hobson, Ouston, & Lee, 1989; Loveland, Tunali-Kotoski, Chen, Brelsford, & Ortegon, 1995; Rutherford, Baron-Cohen, & Wheelwright; 2002; but see Boucher, Lewis, & Collis, 2000). The finding that the affect subtest correlated with almost all other subtests for the control children and with only the focus subtest for the children with autism, suggested that this ability was very much a core prosodic skill in the controls. Indeed, this finding may reflect underlying meta-representational deficits in the children with autism. Thus, in the context of the well-documented social-cognitive deficits in autism, the finding that the children with autism showed significantly lower levels of performance in this task was unsurprising. These findings will be further discussed in the general discussion of this chapter.

Chunking input and focus input subtests

The chunking input and focus input subtests of the PEPS-C test battery measured the understanding of prosody conveyed mainly by variations in speech rhythm. Focus is marked as differentiation between stressed and unstressed words or syllables, achieved by variation in speech rhythm and relative prominence of syllables (McCann & Peppé, 2003). Thus, both of these subtests involved prosodic function, and required processing for semantic and pragmatic meaning. In line with the prediction that children with autism would show deficits in prosodic tasks involving pragmatic function, the findings from the chunking subtest showed that children with autism performed at a significantly lower level, as compared to their controls. Surprisingly, however, although pragmatic and semantic impairments are some of the core deficits of the autistic disorder, no differences were found in performance between the children with autism and their matched controls in the focus subtest. Correlational analysis revealed that, for the children with autism, there was a positive relationship between performance in the chunking and focus subtests, whilst no such relationship emerged for the controls. This finding suggests that the children with autism showed a general ability to understand prosodic rhythm, whilst the control children did not show such a consistent pattern of prosodic abilities in the rhythmic domain. Verbal and non-verbal intellectual ability did not correlate with any of these subtests for the children with autism, whilst they did so for the controls. Interestingly, the findings of experiment five indicated no rhythmic processing deficits at the perceptual level in autism. Thus, this finding needs to be further considered in the light of enhanced perceptual processing and the understanding of the more global functions of prosody by individuals with autism.

As a number of the same children had participated in experiment five, investigating rhythmic processing at the perceptual level of speech, and completed the PEPS-C prosody test battery, it was of interest to directly relate the children's perceptual abilities to the more global functions of rhythm in speech. The paradigm and stimuli used in experiment five were relatively different from the chunking and focus subtests, primarily as the task was purely perceptual, and involved no pragmatic meaning. The chunking and focus subtests, by contrast, were concerned with more sophisticated, global prosodic functions. However, in experiment five, when the processing of the intact speech stimuli for meaning was assessed by control questions, the results indicated that the children with autism showed significantly poorer semantic processing ability than their matched controls. These results might be of particular relevance for the chunking input subtest, as this measure involved the greatest semantic load of all the subtests. In order to examine the relationship between the data from experiment five, and those from the PEPS-C rhythm measures, correlations were carried out between the collapsed scores from experiment five (intact speech plus pseudo-speech), and the chunking and focus input scores for the same children. This resulted in 13 children with autism, and 11 control children, who participated in both studies. The results showed that for the children with autism, a positive correlation emerged between perceptual abilities in the rhythmic domain and performance in the chunking subtest ($r = .59, p < .04$), and between performance in experiment five and the focus subtest ($r = .75, p < .01$), suggesting that the children who were good at perceiving rhythmic patterns in speech were also aware of their global, prosodic function. No such correlations emerged for the control children. Thus, for the children with autism, a strikingly more coherent pattern of abilities was apparent across the perceptual and functional, meaningful aspects, of rhythm in speech in comparison to controls. As perceptually, the expression of focus also involves pitch, the children's performance in the focus subtest was correlated with their collapsed scores from experiment two (speech condition plus music condition). This resulted in 21 children with autism and 17 controls who participated in both studies. Here, a significant correlation emerged for the children with autism ($r = .53, p < .015$), whilst no such correlation was found for the children in the control group. Taken together, these findings suggest that enhanced perceptual abilities were associated with higher-level linguistic competence in children with autism. This will be discussed further in chapter eight. When the children's performance in the semantic processing measure of experiment five was correlated with their score from chunking input subtest, no significant correlations emerged for either group of children. This finding suggests that the chunking subtest was qualitatively different to the semantic processing measure used in experiment five, possibly due to its pragmatic content.

The finding that the children with autism, who showed high levels of performance in the perceptual tasks, also understood the linguistic function of prosodic cues involving rhythm, is striking as neither verbal nor non-verbal intelligence was associated with prosodic processing ability for these children, whilst these abilities contributed significantly to the performance of the control children. Although semantic ability in experiment five was associated with verbal intelligence in autism, the finding that it was not related to prosodic abilities may reflect limitations in the BPVS, the verbal intelligence measure used. This is a receptive test of vocabulary, involving single-word-to-picture mapping. The finding that this did not correlate with the function subtests of the PEPS-C for the children with autism suggest that such verbal abilities bear a limited relation to higher-level, pragmatic linguistic abilities in autism, although they may have been associated with the simpler semantic processing measure used in experiment five. Although on the surface, the experimental task of experiment five and the prosody subtests may seem to have little in common, there is intriguing anecdotal evidence suggesting that some children with autism might have utilised similar processing strategies across these tasks. For example, one boy, when asked how he carried out the tasks, explained that in both experiment five and the chunking subtest, he encoded the stimuli in terms of small, medium, and large chunks, and the position of pauses in between. He then mapped these perceptual patterns to the pictures. Although his verbal ability falls within the normal range, he did not exploit the words in the sentences to repeat back what he had heard (as some control children did), but produced a "hum version" of them. It thus appears that in autism, strategies used for disambiguating the meaning of prosody might be different to those used in typical development. The correlational analysis suggested that these unusual strategies were associated with neither verbal nor non-verbal intelligence scores.

Intonation and prosody input subtests

As the intonation and prosody input subtests were virtually identical to each other, differing only in stimulus length and the type of prosodic form, they are discussed together. The results indicated that whilst both groups of children performed equally well in discriminating between pairs of short laryngographic sounds, the children with autism were significantly poorer at perceiving prosodic form in longer stimuli. The discrepancy between the results from the intonation and prosody subtests was surprising, as the tasks were purely perceptual. Furthermore, in the light of the findings from experiments one, two, three, and four, showing an enhanced ability in the children with autism to perceive pitch in speech, the findings that such children did not outperform their controls was surprising. However, as was mentioned earlier, the standard deviation for the prosody measure was very much larger for the children with autism than it was for their controls. There are two possible explanations for this. Firstly, the stimuli were relatively long, and so the findings may reflect working memory difficulties in some children with autism. This is in line with Kanner's (1943) observation that some echolalic children with autism only repeated back the end parts of utterances. Secondly, it was frequently observed that a number of children with autism showed adverse reactions to the laryngographic sounds used in the stimuli. Consistent with this, children with autism have often been noted to show atypical reactions to auditory stimuli (e.g., Coleman & Gillberg, 1985; Rosenhall, Nordin, Sandström, Ahlsén, & Gillberg, 1999). Indeed, findings from experiment one, incorporating synthesised speech stimuli, indicated that children with autism showed poorer performance in this condition compared with the condition involving intact speech stimuli. However, the strong positive correlation (.79) for the children with autism between performance in the intonation and prosody measures indicated a general ability in a subgroup of these children to perceive intonation form, regardless of sentence length. A further interesting correlation for the children with autism emerged between verbal intelligence and their performance in the intonation and prosody subtests, whilst no other subtests correlated with verbal ability. Thus, although the stimuli in these subtests did not involve phonological content or meaning, the abilities needed to perceive prosodic form appeared to be related to verbal intelligence. By contrast, for the control children, the correlations between verbal intelligence and subtest performance were weakest for the subtests measuring prosodic form (intonation and prosody). It might therefore be speculated that the children with autism and their controls relied on qualitatively different mechanisms when processing prosodic information.

The stimuli used in the intonation and prosody subtests, comprising laryngographic sounds, are comparable with the stimuli of experiment two reported in chapter two. As 21 children with autism and 17 control children participated in experiment two and completed the PEPS-C test battery, correlations were carried out between these data. The children's scores were collapsed across the speech and music conditions from experiment two. This analysis showed that for the children with autism, a positive correlation emerged between scores for experiment two and those for the intonation subtest ($r = .61, p < .01$), and the prosody subtest ($r = 52, p < .02$), indicating a strong interrelationship between pitch processing abilities across all these studies. All correlations for the control children failed to reach significance. Thus, in line with findings from previous experiments, pitch processing abilities in autism appear to be robust across different types of stimuli and paradigms.

Turn-end type input subtest

The turn-end type subtest concerned the differentiation between types of utterances (questioning versus declaring) on the basis of intonation. Here, rising intonation signalled questioning utterances, whilst falling intonation signified declaratives. The results from this subtest indicated no between-group differences in performance between the children with autism and their controls. This finding was surprising, as, according to Relevance theory (Sperber & Wilson, 1995), the understanding of communicative intonation expressed by questioning intonation requires second-order meta-representational ability. As social-cognitive deficits are fundamental to autism (e.g., Lord & Paul, 1997), impairments in this area of prosody would have been expected in such individuals. However, a surprising finding was that the understanding of declarative and questioning intonation appeared to be a core prosodic skill in autism, as this ability was strongly associated with prosodic abilities in other domains of prosody. Thus, this result might have highlighted the importance of meta-representational abilities to prosodic understanding in autism. This finding will be extended and further discussed in chapter seven, where the children's abilities will be assessed at the sentence-level using an analogous task.

It is of relevance here to consider the findings from experiment three, showing that when given a choice to either attend towards perceptual or semantic aspects of speech, children with autism did in most cases process speech at the semantic level. Thus, this study showed that the ability to process speech semantically was intact in autism. As for experiment three, the focus and turn-end type subtests involved only intact speech items. It may thus be suggested that, when presented with purely linguistic stimuli, linguistically able children with autism may find it most natural to focus upon the meaning of speech. This speculation is in line with a finding reported by Happé (1994), showing that when children with autism were asked to read for meaning, this capacity for semantic processing was intact at least in some children. Indeed, in the PEPS-C test battery, the children were specifically trained and thus instructed to focus on the meaning of the stimuli.

As again 21 same children with autism and 17 control children participated in experiment two and completed the turn-end type input subtest, the data from these studies were correlated with each other. Whilst experiment two assessed the children's ability to perceive pitch contours in analogous speech and musical stimuli, the turn-end type subtest tested the understanding of the linguistic, global function of intonation. It should be noted that the stimuli between these two studies were not strictly equivalent as, whilst experiment two included five-syllable sentences (and five-tone melodies), the turn-end type measure comprised single words. The analysis showed that, for the children with autism, a positive correlation emerged between performance in experiment two and in the turn-end type subtest ($r = .50, p < .03$). This result suggests that the children with autism who were good at perceiving pitch contours in both speech and music, were also aware of the linguistic function of pitch in speech. No such correlation emerged for the children in the control group. This finding further reinforced the conclusions that in some individuals with autism, enhanced perceptual pitch processing abilities might relate to good linguistic or communicative ability. Indeed, this was shown to be the case in chapters two and five, where a subgroup of children with autism were identified, who showed enhanced perceptual processing alongside a good ability to process speech for meaning. This will be further examined in chapter eight.

RESULTS FROM PEPS-C OUTPUT TASKS

Due to only 57 per cent of the children with autism completing all the output subtests compared with 100 per cent of control children, only the control children who had an a counterpart with autism with a complete output data set were included in this analysis. This resulted in 12 children with autism and their 12 age- and verbal intelligence matched controls. The raw scores of the children with autism on the BPVS ranged from 57 to 142 (mean age equivalent 9 years, 11 months, *SD* 22.68), and the raw scores of the control children on this measure varied from 34 to 129 (mean age equivalent 9 years, 10 months, *SD* 27.38). The mean MA for the children with autism on the Raven's Progressive Matrices was 11 years, 1 month, and the mean MA for the children in the control group was 11 years, 3 months. The reasons for some of the children with autism not completing the output tasks concerned insufficient expressive language abilities, and/or unwillingness to speak. The children's psychometric and age data are shown in Table 6.4.

Table 6.4 Psychometric- and age data for the children with autism who completed the PEPS-C output tasks and their matched control children

Group	Age			BPVS standardised score			Raven's standardised score		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Children with autism (N=12)	12y5m*	1.95	8y0m-15y8m	91*	19.82	60-135	89*	14.89	66-119
VIQ- and age matched controls (N=12)	12y1m*	2.13	9y4m-16y3m	92*	23.62	64-124	93*	19.69	61-121

*No significant difference between groups for age (*t* (22) = .44, n.s.), BPVS (*t* (22) = -.13, n.s.), or Raven's (*t* (22) = -.54, n.s.)

The means and standard deviations for performance scores in the six PEPS-C expressive subtests and for the total output score for the children with autism and their age- and intelligence matched control children are shown in Table 6.5.

Table 6.5 Means and standard deviations for the output subtest, alongside total scores, for both the children with autism and their age- and intelligence matched controls

PEPS-C subtest	Autism group (N=12)		Age- and intelligence matched controls (N=12)	
	Mean	SD	Mean	SD
Affect output (function)	13.67	3.39	13.42	3.94
Chunking output (function)	9.33**	3.70	12.42**	2.35
Focus output (function)	12.08	3.06	13.33	2.64
Intonation output (form)	14.00	2.91	15.71	0.62
Prosody output (form)	13.38	3.56	15.21	1.62
Turn-end output (function)	10.58**	4.42	14.25**	2.96
Total output score	73.04**	15.00	84.33**	10.83

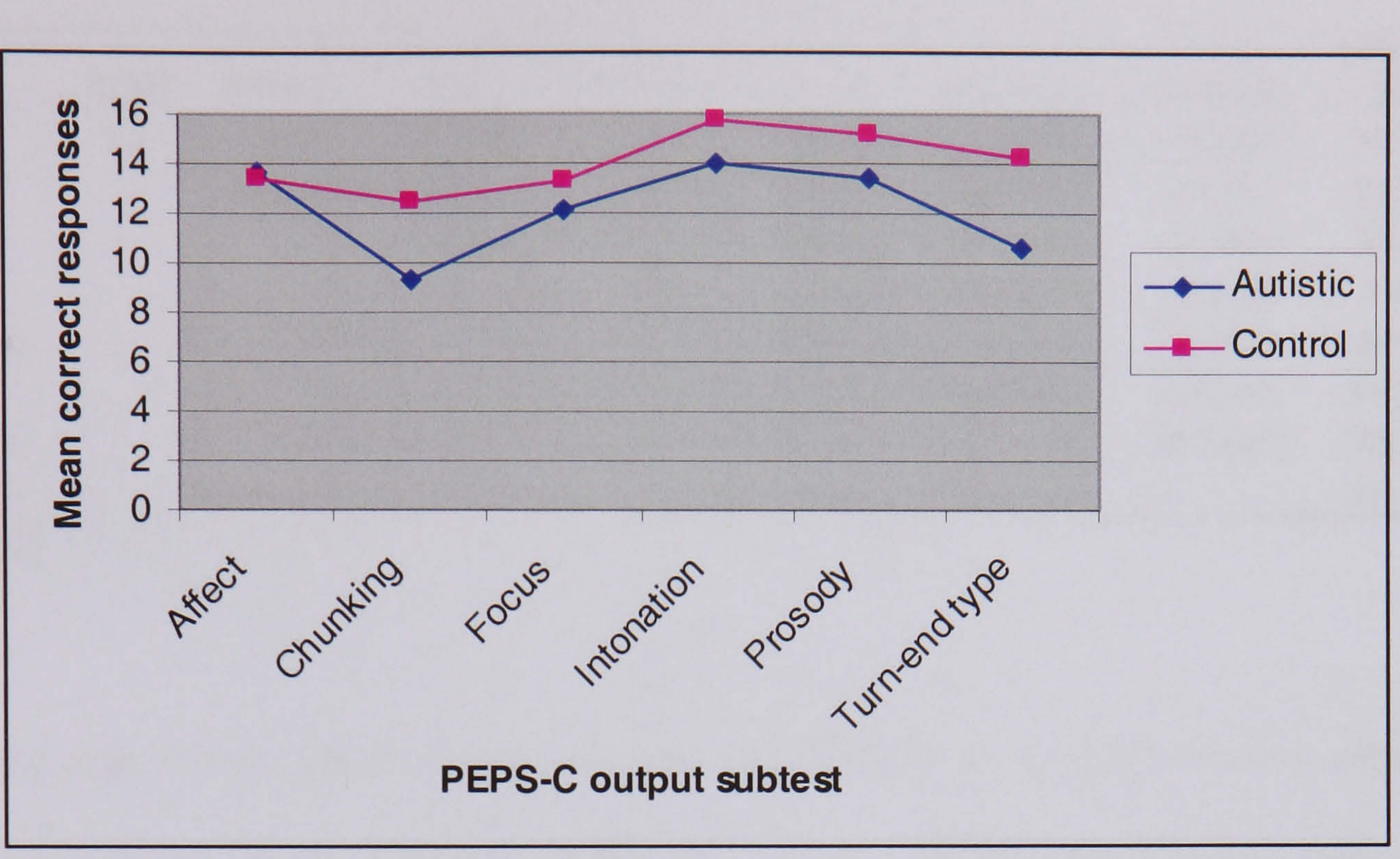
*Maximum score per subtest = 16; maximum total score = 96
**Between-groups difference $p < .05$

In order to examine differences in performance across the six subtests and the total expressive score between the children with autism and their matched controls, independent samples t-tests were carried out on the data. This analysis showed that the control children performed at a significantly higher level compared to the children with autism in two subtests: (1) chunking (t (22) = -2.44, $p < .03$), indicating that the control children were significantly better at disambiguating syntactically ambiguous phrases by the use of phrase boundaries, compared with their autistic counterparts; and (2) turn-end type (t (22) = -2.39, $p < .03$), showing that the children with autism were significantly poorer at producing declaring and questioning intonation compared with their matched controls.

There were no significant between-group differences in performance in the affect (t (22) = .17, n.s.), focus (t (22) = -1.07, n.s.), and prosody (t (22) = -1.62, n.s.) subtests. Furthermore, performance in the intonation output subtest narrowly failed to reach significance (t (22) = -1.99, $p < .06$). However, this finding suggested that the control children showed a trend towards being better able to imitate questioning, declaring, and affective intonation compared with the children with autism, albeit not quite statistically significantly so. Thus, both groups of children were equally competent at producing intonation that expressed liking and disliking, at producing contrastive stress, and at imitating prosody (chunking and contrastive stress) at the phrasal level. With regard to the findings from the focus and prosody measures, earlier discussion in chapter five noted that inconsistent findings have been reported in studies assessing the ability to assign stress in autism. The result that there were no between-group differences in the ability to imitate prosody and intonation were not surprising when considered in the light of the literature reporting that individuals with autism with echolalia are capable of mimicking exact spoken phrases, including the accurate reproduction of the voice quality and prosody used by the speaker (e.g., Kanner, 1943; Local & Wootton, 1996). Analysis of the total output score data showed that, overall, the children with autism were significantly poorer at expressing prosody than their matched controls (t (22) = -2.11, $p < .05$).

The pattern of responding across the six expressive prosody subtests for the children with autism and for their matched control children is illustrated in Figure 6.2.

Figure 6.2 Mean scores in the six output subtests for the children with autism and their matched controls



*Maximum score per subtest = 16

Figure 6.2 shows that both groups of children showed similar patterns of performance across the six expressive subtests.

Finally, correlations were carried out between age, psychometric, and output subtest data for the children with autism and their controls. A summary of this analysis is shown in Table 6.6.

Table 6.6 Relationship between age-, psychometric-, and expressive subtest data for the children with autism (and their control children in parentheses)

	BPVS	Raven's	Affect	Chunking	Focus	Intonation	Prosody	Turn-end type
Age	n/a	n/a	.20(-.48)	.38(-.63*)	-.06(-.38)	.18(-.27)	.14(-.12)	.20(-.15)
BPVS		.32(.86**)	-.59*(.54)	-.06(.66*)	.02(.63*)	.08(.59*)	.11(.50)	.01(.60*)
Raven's			-.02(.34)	.52(.70*)	.35(.40)	.30(.55)	.11(.66*)	.33(.65*)
Affect				.19(.25)	.21(.78*)	-.28(.76**)	-.19(.35)	.41(.54)
Chunking					.50(.20)	.46(.47)	.36(.43)	.63*(.48)
Focus						.49(.45)	.69*(.09)	.81**(.48)
Intonation							.92**(.84**)	.30(.86**)
Prosody								.47(.79**)

* *p* .05; ** *p* .01

Table 6.6 shows that verbal intelligence correlated positively with all subtests except for the affect measure for the control children. In contrast, for the children with autism, the level of verbal intelligence correlated with only the affect subtest, and this relationship was a negative one, suggesting that children with lower verbal ability performed better in this task than those with higher verbal skills. Furthermore, the results showed that non-verbal intelligence did not correlate with any of the PEPS-C output subtests for the children with autism, whilst it did so with the chunking, prosody, and turn-end type subtests for the control children. Thus, the ability to produce prosody was significantly associated with neither verbal nor non-verbal intelligence for the children with autism, whilst both intellectual abilities correlated positively with most subtest scores for the control children. For the control children, the chunking and turn-end type subtest scores correlated positively with both types of intelligence, indicating that the ability to use phrasal stress and questioning and declaring intonation were particularly associated with high levels of intelligence in these children.

The ability to produce affective prosody did not correlate with any of the other subtests for the children with autism. By contrast, for the control children, good performance in this measure was related to the ability to produce contrastive stress, and to imitate declaring, questioning, and affective intonation at the single-word level. Thus, expressive abilities in the affective domain were more central to expressive prosodic skills for the control children than was the case for those with autism.

For the subtests assessing the ability to repeat prosodic form (intonation and prosody measures), a strong positive relationship emerged between the ability to imitate prosody in short and long utterances for both groups of children. Although the t-test analysis indicated that the control children performed better, albeit not quite significantly so, in the intonation measure, the almost perfect positive correlation (.92) for the children with autism showed a robust general ability in a subgroup of these children to imitate prosody, regardless of the prosody type and stimulus length. The intonation subtest correlated positively with the affect, prosody, and turn-end type subtests for the children in the control group, suggesting that the ability to imitate declaring, questioning, and affective intonation was central to general expressive prosodic ability in this group of children. Indeed, the affect and turn-end type subtests essentially are the corresponding function measures of the intonation form subtest.

The turn-end type output subtest assessed the ability to express declaring and questioning intonation. For the children in the control group, a strong positive relationship emerged between the intonation measure and the turn-end type subtest, suggesting that the children, who were good at imitating prosody, were also competent at its meaningful production. Performance in the prosody subtest further correlated positively with the turn-end type measure for the children in the control group. By contrast, for the children with autism, performance in the turn-end type subtest correlated positively with performance in the chunking and focus subtests. Each of these subtests tested prosodic function. These findings suggested that in autism, the ability to produce declaring and questioning utterances was mostly associated with a general ability to generate meaningful linguistic prosody.

The subtests assessing chunking and focus are those that are mostly involved with the production of prosodic rhythm. No significant correlation between these measures was apparent for either group of children. For the children with autism, more correlations emerged between performance in the chunking and focus subtests and in other prosodic measures than was the case for the control children, suggesting that the skills measured by these subtests were more central to general expressive prosodic abilities in the children with autism compared with their controls.

Overall, as is illustrated in Table 6.6, the number of between subtest correlations for the children with autism and their matched control children did not considerably differ between groups, suggesting that for both groups of children, no single prosodic measure was reliably associated with general expressive ability. For the children with autism, good performance in the focus, turn-end type, and prosody subtests was associated with good abilities in other aspects of prosody, whilst for the children in the control group, the ability to repeat intonation appeared to be most associated with general expressive prosodic ability. However, due to the lack of between subtest correlations, no firm conclusions can be made about the specific skills that could explain good general prosodic abilities in the expressive domain in either group of children.

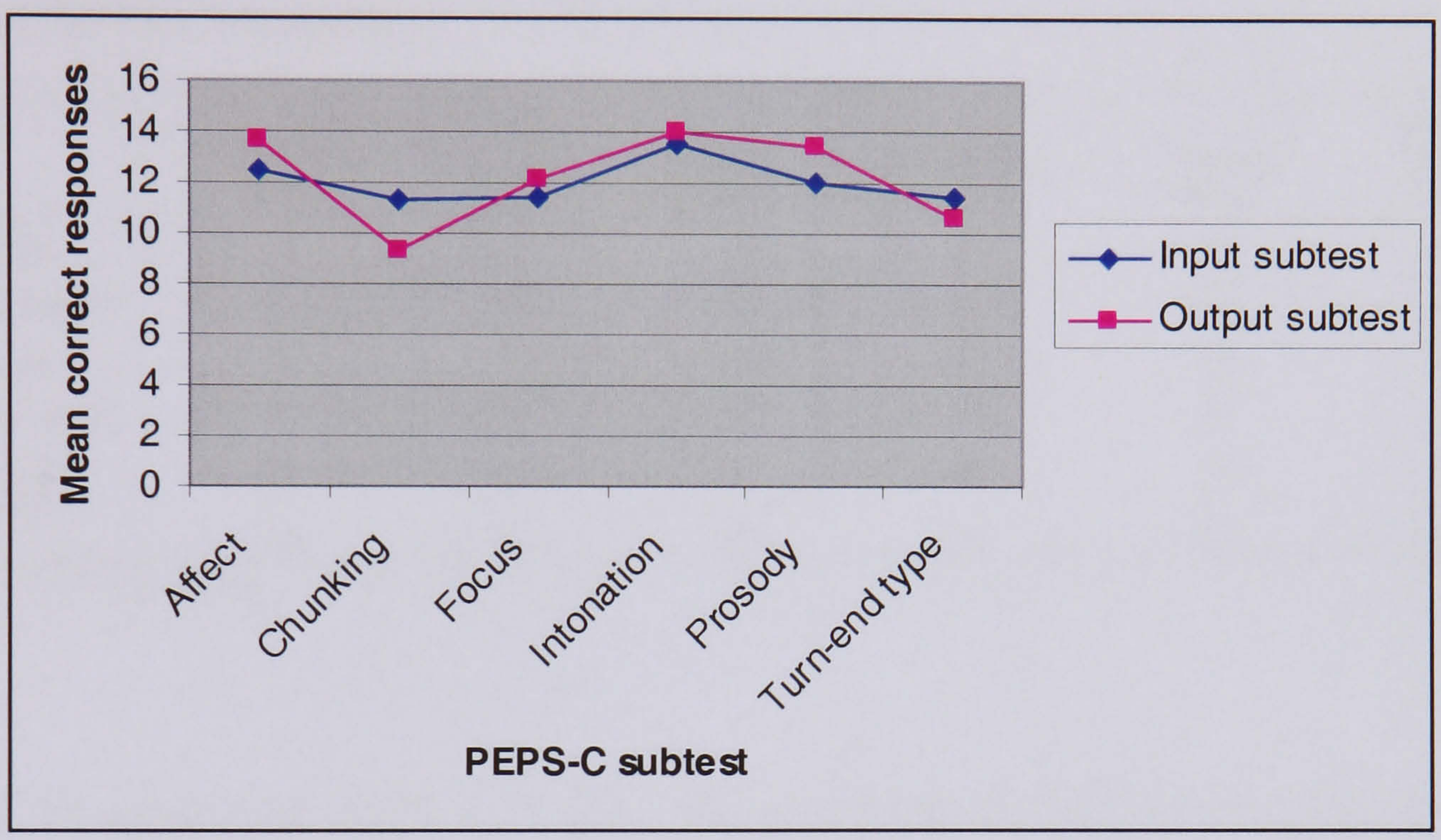
Finally, correlations were carried out between the children's total output score from the PEPS-C, and their age and psychometric data. These results showed that for the children with autism, none of these correlations reached significance. Thus, their expressive prosodic ability was not significantly associated with verbal intelligence, non-verbal intelligence, or age. By contrast, for the children in the control group, a strong positive correlation emerged between general expressive prosodic ability and verbal intelligence ($r = .71$, $p < .001$), and between general expressive prosodic ability and non-verbal intelligence ($r = .79$, $p < .001$). Thus for these children, verbal and non-verbal intellectual abilities appeared to be important for expressive prosodic abilities, as was indeed shown to be the case for receptive prosodic abilities. The findings described in this section will be considered further in the general discussion.

In the following section, the children's performance in the receptive PEPS-C subtests will be related to their corresponding abilities in the expressive domain, in order to present a profile of the general prosodic abilities in these children, and to explore the relationship between receptive and expressive prosodic abilities.

COMPARISON OF THE CHILDREN'S PERFORMANCE IN THE PEPS-C INPUT AND PEPS-C OUTPUT TASKS

Figure 6.3 illustrates the mean performance scores of the children with autism in the receptive and expressive measures of the PEPS-C test battery. It is noteworthy here that the reported input scores are derived from the subgroup of 12 children with autism who completed all the PEPS-C output tasks, and are thus different to the values reported in Table 6.2 earlier in this chapter for the 21 children with autism. The difference between the total input scores for the two samples of children with autism will be considered later in this chapter.

Figure 6.3 Mean number of correct responses made by the children with autism in the PEPS-C input and output subtests



*Maximum score per subtest = 16

Paired-samples t-tests were performed on the data to examine any statistically significant differences between receptive and expressive prosodic abilities in the children with autism. This analysis revealed that the children with autism showed no significant inconsistencies between receptive and expressive abilities in any prosodic domain as measured by the PEPS-C test battery. However, there was a trend towards the children with autism being better able to understand than to produce phrase boundaries (chunking) (t (11) = 2.04, p < .07). A further paired-samples t-test was performed on the total scores from the receptive and expressive PEPS-C measures, and this showed that the children with autism exhibited even abilities in the receptive and expressive domains (t (11) = -.28, n.s.).

Correlations were then carried out between the PEPS-C input and output data for the children with autism. A summary of this analysis is displayed in Table 6.7 below.

Table 6.7 Relationship between performance in the PEPS-C input and output subtests for the children with autism

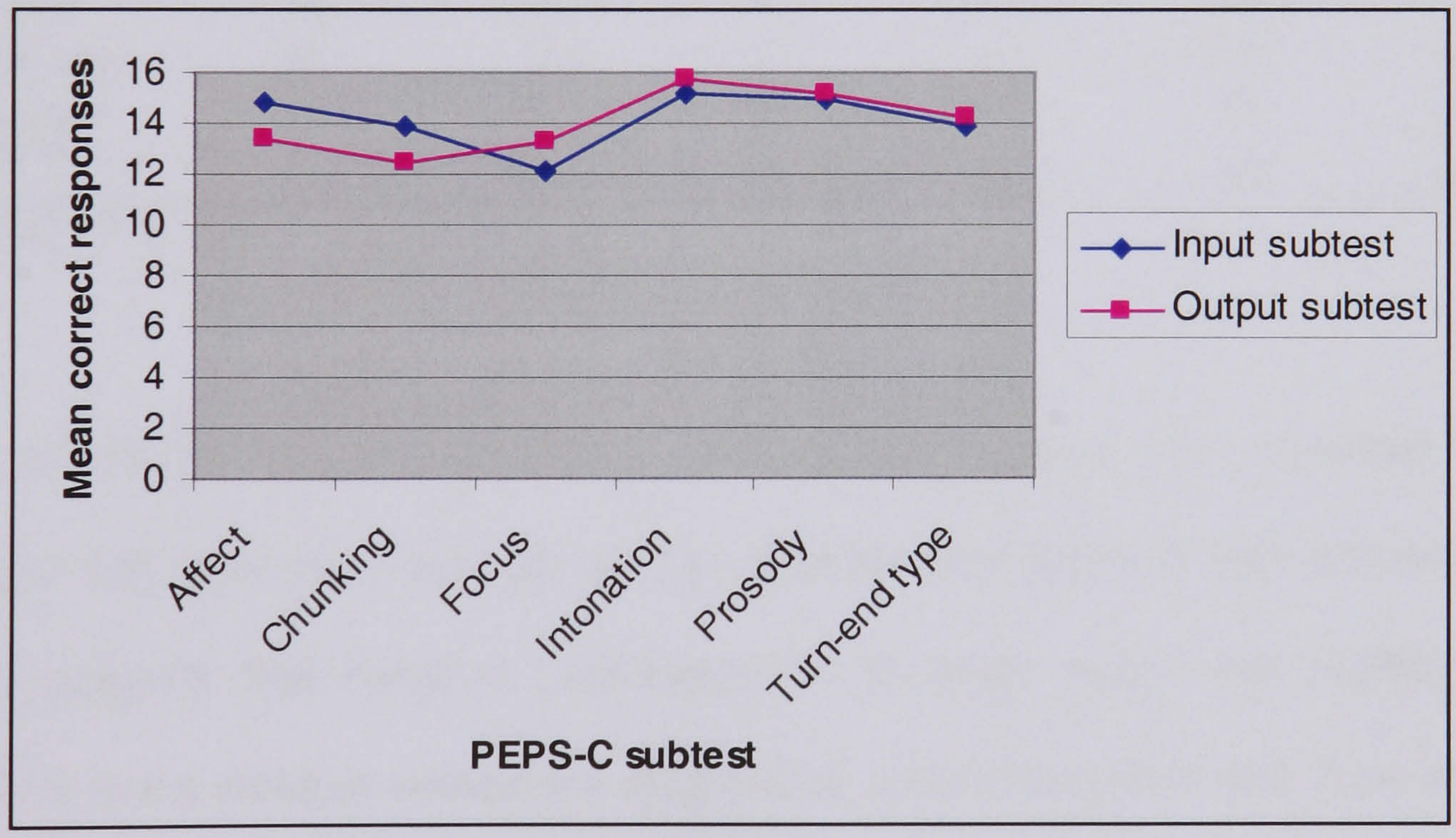
	Affect input	**Chunking input**	**Focus input**	**Intonation input**	**Prosody input**	**Turn-end type input**
Affect output	.20	-.30	.27	-.01	.19	.09
Chunking output	.48	.55	.54	.52	.69*	.58*
Focus output	.09	.19	.43	.33	.48	.72**
Intonation output	.52	.60*	.47	-.10	.20	.39
Prosody output	.44	.48	.49	-.01	.29	.56
Turn-end type output	.28	.39	.66*	.62*	.79**	.91**

* $p < .05$; ** $p < .01$

As can be seen from Table 6.7, only one significant correlation emerged between performance in the corresponding input and output subtest for the children with autism, namely performance in the two parts of the turn-end type measure. This correlation was positive and near perfect at .91. This result suggests that the children with autism, who were good at understanding declaring and questioning intonation, were also highly competent at its expression. The correlation between the chunking input and output subtests was approaching significance (r .55, p = .06), suggesting that some children with autism, who showed good understanding of grammatical phrasing, were also proficient at its production. This finding is surprising in the light of the fact that as a group, the children with autism showed significantly poorer performance in the chunking subtests compared with their matched control children. For all other subtests, performance in the receptive part of the measure did not correspond to performance in the expressive part, suggesting inconsistencies between corresponding receptive and expressive prosodic abilities in autism.

Figure 6.4 illustrates the mean performance scores of the control children in the receptive and expressive measures of the PEPS-C test battery. Again, the reported input scores apply for the subgroup of 12 control children who had an autistic counterpart with a complete PEPS-C output data set. These values are thus different from those reported in Table 6.5. The output data from the complete sample of 22 control children will be reported and discussed later in this chapter.

Figure 6.4 Mean number of correct responses made by the children in the control group in the PEPS-C input and output subtests



*Maximum score per subtest = 16

Paired-samples t-tests were carried out on the data in order to examine any statistically significant inconsistencies between corresponding receptive and expressive prosodic abilities in the children in the control group. This analysis revealed that for these children, performance was even across the six input and output subtests. A t-test performed on the total scores from the receptive and expressive measures further revealed that overall, the performance of the control children was indistinguishable in the receptive and expressive domains of the PEPS-C test battery (*t* (11) = .21, n.s.).

Correlations were then carried out between the PEPS-C input and output data for the control children. A summary of this analysis is displayed in Table 6.8 below.

Table 6.8 Relationship between performance in the PEPS-C input and output subtests for the children in the control group

	Affect input	**Chunking input**	**Focus input**	**Intonation input**	**Prosody input**	**Turn-end type input**
Affect output	.45	-.35	.29	.29	.54	.16
Chunking output	.14	-.01	.61*	.42	.38	.51
Focus output	.35	-.03	.37	.66*	.66*	.26
Intonation output	.48	-.17	.50	.24	.72**	.58*
Prosody output	.40	.22	.63*	.07	.59*	.79**
Turn-end type output	.33	.01	.55	.57	.80**	.77**

* $p < .05$; ** $p < .01$

Table 6.9 shows that for the control children, performance was consistent in the receptive and expressive domains for the prosody and turn-end type subtests. This finding suggests that receptive and expressive prosodic skills were slightly more consistent in the children without the diagnosis of autism compared with those with the disorder. However, taken together with the findings from the children with autism, these results suggest that overall, prosodic abilities were still developing in both groups of children (see Cutler & Swinney, 1987).

Finally, the children's total scores derived from the input and output subtests were calculated and analysed. Table 6.9 shows the means and standard deviations for the total scores across the PEPS-C input and output subtests for the children with autism and their matched controls.

Table 6.9 Means and standard deviations for the total PEPS-C test battery score for both the children with autism and their age- and intelligence matched control children

	PEPS-C total score	
	Mean	**SD**
Autistic (N=12)	145.21	29.00
Control (N=12)	169.17	18.25

*Maximum total score = 192

An independent samples t-test was carried out on the total scores. This analysis revealed that the age- and verbal intelligence matched control children achieved significantly higher total scores on the PEPS-C test battery compared with their autistic counterparts (t (22) = -2.42, $p < .03$). Table 6.10 further shows that the standard deviation was very large for the children with autism (29 versus 18.25 for the control children); indeed, their total scores ranged from 102.5 to 183.5. The corresponding range of scores for the children in the control group was from 135.5 to 187, out of the total of 192. This suggests that, overall, prosodic abilities were substantially more heterogeneous in the autism group, as compared to the control group.

Finally, correlations were performed between the children's total score from the PEPS-C battery, and their age, and psychometric data. This analysis showed that all these correlations failed to reach significance for the children with autism. By contrast, for the children in the control group, overall prosodic competence was associated with verbal intelligence (r .74, $p < .001$) and with non-verbal intelligence ($r = .79$, $p < .001$). These findings suggest that prosodic abilities in the control children were significantly more even in the receptive and expressive domains, and that whilst these abilities appeared to rely upon verbal and non-verbal intelligence, this was not the case for the children with autism.

COMPARISON OF DATA FROM THE SUBGROUPS OF 12 CHILDREN WITH THE DATA FROM THE COMPLETE AUTISM AND CONTROL SAMPLES

Comparison of psychometric and age data from the entire sample of children with autism and their matched controls, reported in Table 6.1, and those for the subgroup of 12 children with autism and their matched controls, reported in Table 6.4, reveal that the main difference concern the children's standardised scores on the BPVS. Namely, these scores are slightly higher for the group of children with autism who completed the PEPS-C output test battery compared with the whole sample mean. For the children with autism, an eight IQ point difference in the standardised BPVS scores between the two groups was in evidence, whilst this difference for the control children was five IQ points. However, these differences are very small, and are less than one standard deviation. A further observation concerns the standardised non-verbal intelligence scores for the control children. Whilst for the children with autism, the mean standardised scores on the Raven's Progressive Matrices were the same (89) for both groups of children (subgroup of 12 versus the total sample of 21 children), a ten IQ point difference was apparent between the two groups of control children in this measure, with the subgroup of 12 children having the higher mean standardised score. Indeed, as non-verbal intelligence had been robustly associated with prosodic skills in the control children, this further strengthens the conclusions that non-verbal intelligence may be crucial for the typical processing of prosody.

Table 6.10 displays the means and standard deviations for the total input and output scores for the total sample of children with autism and their matched controls, and for the subgroup of 12 children with autism who completed the PEPS-C output test battery and their matched controls.

Table 6.10 Means and standard deviations for the total input and output scores for the total and subgroup samples of children with autism and controls

	PEPS-C input total		PEPS-C output total	
	Mean	SD	Mean	SD
Total sample of children with autism (N=21)	67.90	15.79	n/a	n/a
Subgroup of children with autism (N=12)	72.17	15.99	73.04	15.00
Total sample of control children (N=22)	77.69	13.85	78.84	13.18
Subgroup of control children (N=12)	84.83	9.17	84.33	10.83

*Maximum total score = 96

Within-diagnosis comparisons revealed that the performance of the two groups of children with autism was not significantly different in the input tasks (*t* (31) = -.74, n.s.). For the children in the control groups, performance between the total sample and the subgroup sample of children was indistinguishable in both the input (*t* (32) = -1.60, n.s.) and the output (*t* (32) = -1.23, n.s.) subtests. Therefore this analysis indicated that sub-dividing the children for the purposes of analysing the output data did not significantly alter the pattern of results obtained from the entire samples of children.

However, it is interesting to note that when the performance of the children with autism who completed the PEPS-C output test battery (N=12) was compared against that of the total sample of control children (N=22), no significant differences emerged in performance either in the input subtests (*t* (32) = -.78, n.s.) or the output subtests (*t* (32) = -1.17, n.s.). Although the control group included ten more children than that of the children with autism, their age (*t* (32) = .46, n.s.), standardised verbal intelligence scores (*t* (32) = .44, n.s.), and standardised non-verbal intelligence scores (*t* (32) = .27, n.s.) did not significantly differ. Thus, the children with autism who completed the expressive prosody tasks showed levels of performance that were comparable to those of age- and intelligence matched control children. However, when the groups were more carefully matched, the performance of the control children was consistently significantly higher than that of their autistic counterparts. Furthermore, it is noteworthy that, whereas the standard deviation for the control children was substantially smaller for the subgroup sample, the standard deviation for the autism subgroup remained the same as for the whole sample. This suggests that even in the subgroup of children with autism, who were able to complete the expressive prosody tasks, prosodic abilities remained highly heterogeneous.

GENERAL DISCUSSION

The question asked in this chapter concerned how well children with autism would understand the linguistic, global function of such prosodic cues as pitch and rhythm, when embedded in natural speech. In the receptive domain, the findings indicated that children with autism showed deficits in understanding vocally expressed affect, in understanding that syntactically ambiguous sentences can be disambiguated by the use of phrase boundaries, and in the perception of prosodic differences at the phrasal level.

In contrast, the performance of the children with autism and their controls was not significantly different in subtests assessing the understanding of contrastive stress, the ability to discriminate between declarative and question utterances on the basis of intonation, and the ability to perceive intonational differences at the single-word level. The analysis of the data from the control children showed that performance in all receptive subtests correlated with each other, suggesting coherent and even abilities in different domains of prosody. This was not found for the autism group. Overall, children with autism showed significantly poorer understanding of prosody than their matched control children. Furthermore, it was found that general prosodic abilities were associated with verbal intelligence for both groups of children, suggesting that verbal abilities were relatively important for both groups.

Only 57 per cent of the children with autism were able to complete the expressive subtests. The findings from the expressive part of the PEPS-C test battery indicated that the children with autism showed deficits in disambiguating syntactically ambiguous phrases by the use of phrase boundaries, and in producing declaring and questioning intonation. No group differences between the children with autism and their controls emerged in the ability to express affect, to produce contrastive stress, or to imitate intonational and prosodic forms at the single-word and phrasal level. Overall, the children with autism were found to be significantly poorer at producing meaningful prosody than their matched controls.

One important finding showed that the children with autism might have utilised qualitatively different processing mechanisms, when dealing with prosodic information, to their matched controls. More specifically, whilst both verbal and non-verbal intelligence was strongly associated with the control children's performance in all receptive subtests, and with the majority of the expressive subtests, none of the subtest scores correlated with non-verbal intelligence for the children with autism. Furthermore, verbal intelligence only correlated with the form subtests involving no meaning for the children with autism. A related finding showed that non-verbal intellectual abilities appeared to be even more important than verbal abilities for the function, as opposed to form measures, in the control children. This finding was striking given that these children were matched on non-verbal intelligence to the children with autism. However, when the children's perceptual abilities, on the basis of their performance in the previously presented experiments, was related to prosodic comprehension, the findings showed that for the children with autism only, perceptual abilities were strongly associated with prosodic competence. This finding is striking, as it suggests that the children with autism, who showed enhanced perceptual processing of prosody, also understood the global, pragmatic function of pitch and rhythm in speech. As this was not found to be the case for the controls, this raises important questions about the processing mechanisms utilised by the children with autism, as compared to those in the control group, when dealing with prosodic information. As perceptual abilities correlated with both function and form measures in autism, it might be speculated that children with finely-tuned perceptual abilities utilised such skills in "hacking" out solutions to the prosody tasks (see Happé, 1995; Happé, Ehlers, Fletcher, Frith, Johansson, Gillberg, Dolan, Frackowiak, & Frith, 1996). Indeed, the results suggested that, whilst prosodic abilities at the function level were associated with perceptual abilities, they were not associated with either verbal or non-verbal intelligence in autism. This possibility will be further explored in chapter eight. The main findings from the PEPS-C test battery will be discussed under the appropriate prosody type subheadings below.

Affect

The findings from the receptive subtest, assessing the ability to understand the affective connotations (liking and disliking) conveyed by intonation in speech, indicated that the children with autism performed at a significantly poorer level compared with their matched control children. This finding supported the prediction that children with autism would show deficits in prosodic tasks involving pragmatic function. However, in contrast, results from the expressive part of this test revealed that the children with autism were equally competent at producing affective intonation as their matched controls. These findings thus contradicted each other. However, the children's performance in both groups was indistinguishable in the receptive and expressive tasks, suggesting even abilities in both domains. Individual children were found to show inconsistent patterns of performance in the receptive and expressive parts of this subtest, suggesting that the skills required for the processing of affect receptively and expressively were not analogous to each other. One explanation for the observed pattern of results for the children with autism may concern the fact that the receptive task involved voice to face matching. In one study, children with autism were found to be unimpaired in naming affect in voices, whilst their matching of the same voices to faces depicting the affective state was significantly compromised, compared to controls matched for verbal ability (Boucher et al., 2000). The affective states were happiness, sadness, disgust, fear, anger, and surprise. However, a closer inspection of these results revealed that the children with autism showed equal performance in both the affect naming and affect matching tasks. Although superficially, this finding may suggest a matching problem rather than one in affective processing per se in autism, the authors suggested that the observed matching deficit was an additive effect of impaired voice and impaired face processing. The good performance in the affect naming task was at least partially attributed to the fact that children with autism are specifically trained to name emotional states in schools. It is also unlikely that the results of the current study reflected cross-modal matching deficits as all of the children tested had taken part in previous experiments reported in this thesis, many of which involved auditory to visual matching, where no such impairments were found.

Whilst the ability to perceive vocally expressed affect was associated with general receptive prosodic skills in the control children, this was not the case for the children with autism. One possibility is that the between-group differences reflected differences in the children's underlying meta-representational abilities, where deficits are commonly reported in individuals with autism. Indeed, such abilities are particularly strongly associated with the receptive task, as children were required to infer the speaker's mental state on the basis of intonation only. In contrast, the expressive task involved the expression of one's own mental state via intonation, thus having no reliance upon the understanding of another person's mental state. The finding that in the control children, the ability to perceive affect was associated with prosodic skills in other domains (chunking, focus, prosody, and turn-end type), may suggest that intact meta-representational abilities were strongly associated with prosodic understanding in these children. In support of this was the positive correlation between verbal intelligence and performance in this subtest for the control children, as verbal intelligence has been shown to closely correlate with children's performance in theory of mind tasks (e.g., Dahlgren & Trillingsgaard, 1996; Happé, 1995; Tager-Flusberg & Sullivan, 1994).

It is noteworthy here that the PEPS-C affect measure incorporated the mental states of liking and disliking, thus involving no sophisticated mental state terms (cf. Rutherford et al., 2002). There is evidence to suggest that desire may be one of the easiest mental states for children to understand. As the affect subtest used a context where the understanding of like or dislike of food items was tested, this can be seen as being essentially related to the comprehension of desire. In a study of children with, variously, Williams syndrome, Prader-Willi syndrome, and non-specific intellectual impairment, children were asked to explain an individual's actions using desire, emotion, and cognitive mental state terms (Tager-Flusberg & Sullivan, 2000). The findings indicated that within each group, the children's performance was highest with the stories involving desire and emotion. Similar findings have been reported for children with autism (Tager-Flusberg, 1992), namely, that children with autism used significantly fewer cognitive mental state terms in their spontaneous speech compared with lexical terms for desire and emotion. In the light of these experiments then, the receptive findings from the PEPS-C subtest would specifically implicate a deficit in the children with autism in understanding this relatively low-level mental state *in another person*, as their good performance in the expressive part of the affect subtest suggested no impairment in understanding what the terms liking and disliking actually mean.

Previous research examining emotional prosody in individuals with autism has reported inconsistent findings, and no known studies have assessed both receptive and expressive abilities in the same individuals. In one expressive study, von Benda (1984) reported findings from speech therapists' analyses of prosodic features of speech of children with autism and of control children with language impairment. The findings showed that the children with autism used random and careless prosodic contours in their speech, to the extent that their use of affective prosody often conflicted the meaning of their utterances. However, no details about the affective states or length of the speech samples are available. These findings appear to contradict the current results obtained from the affect input subtest; however, it is plausible that the children's speech samples in von Benda's study were longer than single words, and so the differences may reflect difficulties in expressing affective prosody in spontaneous speech situations in autism. In the receptive domain, a study by Van Lancker, Cornelius, and Kreiman (1989) tested the abilities of children with autism, typical development, and schizophrenia, to label four affective intonation patterns (sad, happy, angry, and surprised) in speech samples. The findings showed that children with autism of all ages showed significantly poorer performance compared with that of both of their control groups. These results are consistent with a study by Rutherford and colleagues (2002), where adults with autism were found to show an impaired ability to interpret complex affective states in speech samples. Thus, these studies are consistent with the current results from the affect input subtest. Interestingly, however, an electrophysiological study by Erwin, Van Lancker, Guthrie, Schwafel, Tanguay, and Buchwald (1991) found the processing of affective prosody to be normal at the neural level in adults with autism. However, the present study tested children with autism rather than adults, so these findings might not necessarily generalise to them. Furthermore, there are important differences in the stimuli used between the cognitive and electrophysiological experiments: for example, whereas the stimuli in Rutherford and colleagues' study consisted of sophisticated mental state terms, such as "contemplating" and "intriguing", the experiment by Erwin and colleagues only tested the ability to discriminate between "Bob" uttered in happy and angry prosody. Thus, it is possible that the inconsistent findings reflect differences in the relative difficulty between understanding and interpreting complex mental states (e.g., intriguing) and more basic ones (e.g., happy) in speech. A further problem concerns the fact that, in Rutherford et al.'s study, no understanding of the complex mental states incorporated in the stimuli was tested prior the administration of the experimental task.

It is of interest to consider the children's performance in the intonation subtests, as they assessed the ability to perceive physical differences in intonation, and to imitate intonation expressing liking and disliking. The results from both receptive and expressive subtests indicated no significant differences in performance between the children with autism and their matched controls. Thus, as the children with autism were not impaired relative to their controls in perceiving prosodic intonation signalling liking and disliking, or in imitating such intonation, it might be speculated that these children's impairments in the affect input task pertained to meta-representational abilities.

Chunking

The chunking subtests assessed the ability to perceive and produce syntactically ambiguous phrases disambiguated by prosody. The findings from both input and output subtests indicated deficits in children with autism relative to their matched control children, thus lending support to the prediction that children with autism would show difficulties in tasks involving prosodic function. Indeed, when the findings from the entire PEPS-C test battery are considered together, the most drastic impairments in prosodic processing in the children with autism appeared to be in chunking. As the chunking subtest was the most semantically loaded PEPS-C measure, it is plausible that the observed impairments partly reflected semantic deficits in the children with autism. Such impairments have been found in the same group of children with autism in the previously reported experiments. However, semantic processing abilities, as assessed in experiment five, did not relate to the children's performance in the chunking input subtest. Here, the findings showed that whilst children with autism were significantly better at perceiving rhythmic patterns in intact speech compared to their matched controls, they were significantly poorer than controls at processing the speech samples for meaning. A possible explanation for this discrepancy concerns the fact that the control questions used in experiment five did not require the parallel processing of prosody and semantics. Thus, the chunking subtest presented greater linguistic processing demand. Although both groups of children exhibited similar abilities in the receptive and expressive domains, individual children were found to show inconsistent patterns of performance in the receptive and expressive parts of the test in both groups. However, this correlation was approaching significance for the children with autism, suggesting that a subgroup of children with autism showed highly proficient processing of this type of prosody, whilst no such subgroup was apparent in the control group. This is surprising in the light of the finding that, overall, the children with autism performed significantly worse than their controls in the chunking measure.

As has been mentioned previously, chunking is a grammatical function of prosody, and according to Cruttenden (1997), the segmentation of utterances into phrases can be achieved by the use of pause, stress, intonation, and final syllable lengthening. This is to say that the prosodic difference in pronunciation between "fish, fingers" (two items) and "fish-fingers" (one item) is an existence or absence of a pause between the first and the second noun, and the duration of the final syllable of the first noun, which is lengthened if it indicates the end of a "chunk". Thus, the physical discrimination largely relies upon the ability to perceive subtle timing properties of speech, and, to a lesser extent, intonation. The prosody input subtest incorporated stimuli where intact speech phrases containing chunking were treated so that no phonological information was audible. The results from this subtest suggested that the performance of the children with autism was not associated with performance in the chunking measure, suggesting deficits at both form and function levels in the children with autism. However, this suggestion is inconsistent with findings from experiment five, where children with autism were shown to have preserved perceptual processing of rhythm. Rather, as has been argued previously, the poor performance of the children with autism in the prosody input subtest may not have reflected these children's true perceptual abilities due to the adverse nature of the stimuli. A striking finding showed a positive correlation between performance in experiment five and the chunking subtest for the children with autism, suggesting that the children who were proficient at perceiving rhythm patterns in speech stimuli also understood the global linguistic function of rhythm in speech (chunking). Furthermore, as findings from experiment five indicated intact rhythmic processing abilities in the children with autism, it may be suggested that their poor performance in the chunking subtest reflected deficits in semantic and/or syntactic processing, rather than impairments in temporal processing, as was suggested by the findings from the receptive prosody measure.

As was discussed in the introduction to chapter five, previous research into grammatical phrasing in autism has reported inconsistent findings. A receptive study by Paul, Augustyn, Klin, Volkmar, and Cohen (2000) found deficits in children with autism in appreciating the timing and intonational cues at phrase boundaries. Although no expressive abilities were tested, the results lend support to the current findings. In contrast, two expressive studies found that individuals with autism used grammatical pauses appropriately in their speech (Fine, Bartolucci, Ginsberg, & Szatmari, 1991; Thurber & Tager-Flusberg, 1993). However, an experiment by Fosnot and Jun (1999) showed that children with autism used grammatical pauses accurately significantly less often than controls, and also showed problems with imitating the timing and chunking patterns of adult speech. In the current study, the prosody output subtest assessed the children's ability to imitate the chunking patterns in speech, and here no significant differences emerged between the children with autism and their matched controls. Thus, it appears that the underlying capacity for producing such utterances was intact in the children with autism, but that the problem specifically resided at the semantic or linguistic level. It is of relevance here to consider the findings from a study by Bormann-Kischkel, Amorosa, and von Benda (1993). The authors analysed the time structure (duration of sounds, syllables, and breath pauses) of recorded speech samples of children with autism, typical development, and severe speech and language disorders. The recordings were made in situations that involved the imitation of sentences, reading, narrating a story from pictures, and answering questions. The analysis showed that the time structure of the speech of the children with autism was atypical compared to that of the other groups of children. Rather than being characterised by a general irregularity of timing, these children's speech included abnormally lengthened sounds together with "speech rushes", that were not explainable by the structure of the words, by problems in articulation, or by the semantic content. Thus, these findings are in line with the present findings from the chunking output subtest. Taken together, due to the small number of studies that have been carried out into the use and understanding of phrase boundaries in individuals with autism, it is extremely difficult to draw any firm conclusions about such abilities. Further problems concern the differences in methodology used in the above studies, which make the findings difficult to compare against each other. To illustrate, whilst the study by Fine and colleagues analysed recorded samples of spontaneous speech generated in an interview situation, Thurber and Tager-Flusberg analysed narratives elicited using a picture book, and Fosnot and Jun analysed reading prosody. No information about separate analyses of data gathered from different speech situations was given in Bormann-Kischkel and colleagues' study. Thus, the design of the current study is most comparable with that used by Thurber and Tager-Flusberg, as in both studies, participants were required to tell the experimenter what they saw in pictures.

Focus

The findings from the focus subtest, assessing the ability to understand and produce contrastive stress, indicated no significant between-group differences in the receptive and expressive parts of the test. Within-diagnosis comparisons indicated that the children's performance in both groups was equal in the receptive and expressive parts of the test. However, correlational analysis revealed that individual children exhibited inconsistent patterns of performance in the receptive and expressive subtests. Indeed, one explanation for this discrepancy might be that in the receptive domain, for both groups of children, the focus subtest appeared to be the most difficult task of all six measures. Interestingly, correlational analysis on the receptive data from the children with autism suggested that good understanding of contrastive stress was associated with good skills with other types of prosody, indicating to be one of the core prosodic abilities for these children.

As both the chunking and focus subtests pertain to prosodic rhythm, it is interesting to compare the performance of the children with autism, relative to their matched control children, in these two subtests. As both subtests assessed prosodic function, involving top-down processing for meaning, the finding from the focus subtests showing no deficits in autism was surprising. Furthermore, the findings failed to support the hypothesis that prosodic impairments in autism would be particularly evident at the function level. However, for the children with autism, a strong positive correlation emerged between the ability to perceive minor phrase boundaries (chunking) and contrastive stress (focus), whilst no such relationship was apparent for the control children. Thus, a subgroup of children with autism showed good receptive abilities in both measures assessing prosodic rhythm, confirming earlier conclusions of this type. Furthermore, for the children with autism, perceptual abilities measured in experiment five correlated positively with performance in the focus subtest, whilst no such correlation emerged for the controls. Intriguingly, these results suggest that the children with autism possessed more coherent abilities in the rhythmic domain of speech, at both form and function levels, than were evident for their controls.

In order to cast light on this surprising pattern of results, it is important to consider how the perceptual properties produced by chunking might be different from those produced by contrastive stress. As has been mentioned earlier, the function of contrastive stress is to bring into focus one part of an utterance that is more important than the other parts. Interestingly, investigations into child language acquisition have reported that contrastive stress emerges very early in development as a pragmatic tool (Hornby & Hass, 1970). Indeed, as the use of stress is heavily dependent upon the pragmatic intention of the speaker, McCann and Peppé (2003) suggested that an individual exhibiting misassigned stress patterns may have a deficit in the pragmatic rather than in the prosodic domain. Perceptually, an utterance containing contrastive stress is commonly associated with greater variation in prosodic forms, such as pitch height, pitch movement and loudness, than an utterance containing no stressed segments (McCann & Peppé, 2003). Thus, whilst acoustically, chunking is largely manifested by timing and durational factors, focus involves pitch. In the light of the current results, it may then be speculated that the relatively good performance of the children with autism in the focus subtest may, at least partially, be explained by their excellent pitch discrimination abilities in the speech domain. Indeed, in support of this, a correlational analysis showed that the performance of the children with autism in experiment two, assessing their ability to process pitch contours in speech and music, and performance in the focus subtest, were associated with each other. This suggestion derives further support from the correlation showing that, for these children, performance in the focus and prosody subtests was associated, suggesting no deficits at the form level in autism. One possible explanation for the finding that the children with autism did not show apparent prosodic deficits is that, as suggested in studies that have tested theory of mind abilities in children with autism, such individuals may use verbal and general reasoning skills, rather than pragmatic abilities, in "hacking" out solutions to such tasks (e.g., Happé, 1995). It may then be the case that similar compensatory strategies were used by the children in the current study. Furthermore, in the expressive domain, a positive correlation emerged between the ability to produce contrastive stress (focus subtest) and to imitate chunking and focus (prosody subtest), suggesting no deficits at the production level in autism either. No such correlation emerged for the children in the control group. In contrast, as was mentioned previously, as successful performance in the chunking subtest relied primarily upon complex syntactic-semantic computations, it may be that the poor performance of the children with autism specifically reflected semantic deficits.

Previous studies examining the use and understanding of contrastive stress have consistently reported deficits in individuals with autism. Whilst no such were found in the focus subtest, it should be noted that, as was mentioned in the introduction to chapter five, only a handful of studies have been carried out, and these are constrained by methodological problems. Furthermore, no known study has assessed both receptive and expressive abilities in the same individuals with autism. Only one study has investigated receptive abilities in autism, and as this was a small pilot study, it provides very limited information (Paul et al., 2000). The authors reported that participants with autism were poorer than their controls at comprehending contrastive stress, although they provided no information about statistical significance. In the expressive domain, a study by McCaleb and Prizant (1985) found that children with autism used contrastive stress for marking new versus old information in an atypical fashion. However, this study included only four participants, making the representativeness of the findings questionable. In a similar vein, Baltaxe (1984) reported that children with autism misassigned stress twice as often as their typically developing controls. A striking characteristic of their errors was the tendency to stress many syllables of an utterance instead of one. Again, only seven children with autism were tested. In addition, studies by Fine et al. (1991) and Shriberg, Paul, McSweeny, Klin, Cohen, and Volkmar (2001) reported atypical stress assignment in participants with autism. Both studies tested large samples of individuals with Asperger syndrome and high-functioning autism. However, the age range was very broad (seven-50 years), making it difficult to draw generalisations from the results. This is particularly difficult as no analysis of age differences was carried out to explore developmental differences. Finally, a study by Bormann-Kischkel and colleagues (1993) analysed speech samples of children with autism and controls for intensity or loudness characteristics. This analysis showed that the intensity of speech of individuals with autism was more varied than that of their controls in the overwhelming majority of cases; extreme loudness of unstressed syllables was also frequently noted. Taken together, the current findings seem to contradict those reported in the literature. However, as no information was available on the corresponding expressive or receptive abilities of the individuals tested in the experiments described above, it may be that expressive deficits may arise as a result of an underlying receptive deficit in individuals with autism.

Intonation

The intonation subtest assessed the ability to perceive and imitate declaring, questioning, and affective intonation at the single-word level. Findings from the receptive and expressive subtests showed no significant differences between children with autism and their matched control children, although the controls showed a trend towards better expressive ability. As these subtests assessed prosodic form, the hypothesis stating that prosodic impairments in children with autism would mainly reside at the function level was therefore supported.

An analysis comparing within-groups performance in the receptive and expressive parts of the test revealed that both groups of children possessed similar abilities in both domains. However, individual children showed inconsistent patterns of performance in the receptive and expressive parts of the test. Furthermore, children with autism showed the highest levels of performance in the receptive intonation subtest relative to the other measures of the PEPS-C. However, as the task was to make same-different discriminations between pairs of laryngographic sounds on the basis of their pitch direction, it is surprising that the children with autism did not outperform their controls. One possibility for this inconsistent finding relative to findings from experiments one, two, three and four, reported earlier in this thesis, is that some of the children with autism found the stimuli unpleasant. In support for this suggestion, when children's performance in experiment two, assessing the ability to extract four different contour shapes from speech and music stimuli, was compared against their performance in the intonation input subtest, a strong positive correlation emerged for the children with autism. No such correlation was found for the control children. Thus, the sophisticated pitch analysis skills of these children were robust against different types of auditory stimuli and varying experimental paradigms.

Prosody

The prosody subtests assessed the ability to perceive and imitate prosodic forms at the phrasal level, achieved by chunking and contrastive stress. The findings from the receptive task indicated that the children with autism performed at a significantly poorer level relative to their matched control children. Thus, this result failed to support the hypothesis that prosodic impairments in autism would reside largely at the function level. This finding was surprising as this subtest was virtually identical to the intonation measure where no between-group differences were observed, with the exception that the stimuli pairs were longer. However, a large standard deviation for the children with autism indicated that performance levels were highly heterogeneous within this group. An analysis of the expressive data showed no between-group differences in the ability to imitate phrases containing contrastive stress and chunking. Within-diagnosis comparisons revealed that performance levels were even in the receptive and expressive domains for both groups of children. An interesting finding was that, whilst receptive abilities corresponded to expressive abilities in the children in the control group, this was not the case for the children with autism. Indeed, for the control children, the ability to perceive longer prosodic forms (prosody input subtest) was a core prosodic skill. This finding is consistent with the typical profile of prosodic development, whereby abilities at the form level are considered to be prerequisite for skills at the function level.

It may be suggested that the poorer performance of the children with autism in the receptive task may indicate impaired auditory perceptual abilities with regard to recognising pause, loudness, and duration factors in speech. Such abilities have been suggested to be prerequisite for the abilities required for the understanding of chunking and focus in speech (Peppé et al., 2003). However, as was discussed in relation to the findings from the receptive prosody subtest, the poor performance of the children with autism was likely to have arisen due to the nature of the stimuli, which was often perceived as being unpleasant. In support of this, a strong positive correlation between performance in the intonation and prosody subtests was found for the children with autism, indicating intact auditory discrimination skills in a subgroup of children. Furthermore, this sample of children with autism has been shown to possess enhanced pitch discrimination abilities in the speech domain in the previously reported experiments.

Turn-end type

The findings from the turn-end type subtest, assessing the ability to understand and produce declaring and offering intonation indicated firstly, that both groups of children showed equal levels of understanding of questioning versus declarative intonation over single-word "conversational turns". Therefore the prediction that children with autism would show deficits in tasks involving pragmatic meaning was not supported. This finding was surprising in the light of the fact that pragmatic impairment is considered to be a universal feature of autism (Lord & Paul, 1997; Ramberg, Ehlers, Nydén, Johansson, & Gillberg, 1996). Secondly, for the children with autism, performance in this task did not correlate with verbal intelligence. As children's performance in theory of mind tasks has been shown to strongly correlate with standardised verbal intelligence measures, such as the BPVS (e.g., Cutting & Dunn, 1999; Happé, 1995; Tager-Flusberg & Sullivan, 1994), this finding may suggest that the children with autism utilised different processing mechanisms to those in the control group. This finding is also surprising in the light of Relevance theory (Sperber & Wilson, 1995), which posits that the ability to understand communicative intention conveyed by questioning intonation requires second-order meta-representational ability. Taken together, it is puzzling that no support for the previously reported pragmatic deficits in autism was found in this study. Thirdly, the results from the output task showed that children with autism were impaired relative to their matched controls in producing offering and declaring intonation. A possible explanation for the reported expressive deficits in the children with autism may concern the fact that, as was suggested by Kanner (1943), children with autism often show a reduced tendency to ask questions, together with a reduced drive to communicate (Frith, 1989b). It may thus be that, as they might not perceive others as a valuable source of information, questions bear reduced communicative importance for children with autism, which may in turn manifest as an underdeveloped ability to use intonation communicatively. However, as within-diagnosis comparisons only included data from 12 children, findings showed that within both groups of children, receptive and expressive abilities were even. Furthermore, receptive and expressive abilities were associated with each other in the same children, suggesting that for both groups of children, robust receptive and expressive skills were in evidence. Indeed, this correlation was near perfect for the children with autism (.91).

The finding that the ability to understand and produce declaring and questioning intonation was a core prosodic skill in autism was surprising when contrasted with the control children, for whom performance in the prosody input form subtest was associated with good skills in other areas of prosody. One possibility is that this finding reflected the importance of underlying meta-representational abilities in the processing of prosody in the children with autism. In support of this, results from the focus input subtest showed that the performance of the children with autism in this task was also associated with general prosodic abilities in other domains. As both the turn-end type and focus subtests relied upon pragmatic understanding, it seems plausible to speculate that the high number of between subtest correlations with these measures reflected meta-representational understanding in the children with autism. This will be discussed in more detail in chapter seven. It is surprising, however, that performance in the receptive turn-end type subtest was not associated with performance in the affect input task, as this also relied upon meta-representational understanding. Furthermore, strong correlations between the receptive turn-end type measure and those of intonation and prosody suggested a close relationship between the ability to perceive prosodic differences, and to comprehend such stimuli, at the function level in autism. Indeed, when the children's performance in experiment two, assessing the ability to process pitch contours in speech and music, was compared with their performance in the turn-end type input subtest, a strong positive correlation emerged for the children with autism only. Thus, this finding indicated highly coherent pitch abilities across perceptual and high-level linguistic domains in the children with autism.

A possible further explanation for the discrepancy between receptive and expressive abilities in the children with autism in the turn-end type subtests may be that their deficits in understanding the two types of intonation were masked by the forced choice design of the task. Here, of course, guessing may have contributed towards children's scores. Furthermore, as Relevance theory suggests that the understanding of questioning intonation is a higher-level process than that involving declaring intonation, the analysis of the data as a single, collapsed score, may also have masked specific deficits in one domain. This will be examined and discussed further in chapter seven.

In an expressive prosody study by Baltaxe, Simmons, and Zee (1984), the spontaneous declarative utterances of six children with autism were analysed for frequency range, terminal fall, intonation contour, declination effect, and co-variance of frequency and intensity. The findings indicated that when compared to typically developing control children, the children with autism presented either very wide or narrow frequency ranges in their speech. Although this study only included a small number of participants, the findings suggested abnormalities in the use of pitch variation in speech by children with autism. In a similar study, Bormann-Kischkel and colleagues (1993) analysed fundamental frequency analyses of speech samples from children with autism. These findings showed that the speech of children with autism had greater fundamental frequency ranges than that of typically developing children. However, the abnormalities in the vocally expressed pitch appear to be restricted to the speech domain in autism, as interestingly, this study further showed that children with autism were able to sing melodies correctly. Thus, these findings suggest that these children's inability to control pitch was specific to the speech domain. However, difficulties with controlling pitch in speech may, at least partially, explain the findings of the current study for some children. An investigation by Fosnot and Jun (1999) assessed the ability of four children with autism to produce questioning and declaring intonation, by asking the children to read pairs of short sentences which either finished with a full stop or a question mark. The control groups included children with typical development and those with a stutter. The findings showed that the children with autism failed to discriminate between questions and statements, and pronounced all sentences with a declarative intonation, whilst both control groups showed good levels of performance. A similar tendency was noted in the turn-end type output measure of the current study, where several children with autism failed to produce questioning intonation. Fosnot and Jun's study further assessed the ability of the children to imitate declaring and questioning intonation patterns. These results showed that whilst the children with autism performed better in this task compared to the one described above, their ability to imitate intonation correlated with the severity of autism. Indeed, this led the authors to suggest the ability to produce prosody might be a measure of the severity of their autism. Finally, only one known study has assessed the understanding of turn-end types receptively in autism. In this electrophysiological investigation by Erwin and colleagues (1991), 11 adults with autism were asked to discriminate between "Bob" uttered as a question versus "Bob" uttered as a statement, whilst their patterns of neural activation were measured. Surprisingly, the findings indicated normal neural processing of prosody in the individuals with autism. However, as the participants tested in this study were adults, the findings may not generalise to children. Taken together, behavioural findings have consistently found abnormalities in individuals with autism with regard to understanding and expressing questioning and declaring intonation. Thus, the current findings from the expressive subtest are in line with those reported previously. The surprising finding from the receptive turn-end type subtest, showing that pragmatic abilities were intact in autism, will be further explored and discussed in chapter seven, where it will be extended to a more ecologically valid communicative context.

Chapter Seven

Understanding of the Pragmatic Meaning of Rising and Falling Intonation in Speech by Children with Autism

Summary: This study measured the understanding of the pragmatic-linguistic use of intonation at the sentence level. The ability to understand questioning versus declarative utterances has already been assessed at the single word level by the turn-end type input subtest of the PEPS-C test battery (Peppé, McCann, & Gibbon, 2003), which showed indistinguishable performance between children with autism and their age- and verbal intelligence matched controls. As the findings from the PEPS-C test also suggested that such prosodic abilities in children with autism might reflect wider social-cognitive abilities, it was of interest to extend the findings from the turn-end type input subtest to more communicatively valid analogous stimuli. The findings from the current study contradicted those obtained from the turn-end type input subtest of the PEPS-C battery in showing that under more ecologically valid conditions, children with autism

showed marked deficits in pragmatic processing. The studies were discussed in the framework provided by Relevance theory (Sperber & Wilson, 1995), which makes specific predictions about meta-representational abilities in relation to prosodic competence.

EXPERIMENT SIX: DISCRIMINATION BETWEEN STATEMENT AND QUESTION SENTENCE PAIRS DIFFERING IN INTONATIONAL COUNTOUR

INTRODUCTION

Chapter six was concerned with formally assessing prosodic abilities in children with autism and their age- and verbal intelligence matched controls, using the PEPS-C test battery. The majority of these children had participated in the experiments reported earlier in this thesis, which have shown that children with autism have consistently outperformed their matched control children in tasks involving pitch processing at the perceptual level in speech stimuli. At the same time, their processing of speech for meaning has been shown to be compromised in most cases. Whilst the findings from the PEPS-C test battery showed that, overall, children with autism were significantly poorer than controls at comprehending and producing speech prosody, there was a high level of heterogeneity in the prosodic abilities of the children with autism. The aim of the following experiment was to address some outstanding questions raised by the performance of the children with autism in the turn-end type subtests of the PEPS-C test battery. More specifically, the finding that children with autism were unimpaired in their ability to understand communicative intention expressed by questioning intonation was surprising, given the pragmatic impairment that is considered to be one of the cardinal and universal features of the autistic spectrum disorder (Ramberg, Ehlers, Nydén, Johansson, & Gillberg, 1996; Tager-Flusberg, 2001b). Indeed, Relevance theory (Sperber & Wilson, 1995) proposes that intentions are mental states, and that the understanding of communicative intention requires second-order meta-representational ability. A further surprising finding from the results from the PEPS-C test battery was that the abilities required for discriminating between questioning and declaring intonation were particularly strongly associated with general prosodic abilities in the receptive and expressive domains in autism. As the turn-end type subtests relied upon the ability to represent intentions of others, this finding may thus suggest that prosodic competence in autism was associated with good meta-representational abilities. Experiment six was designed to address all these issues. The stimuli of the PEPS-C turn-end type input task comprised one-word food items, whilst an analogous experiment six will measure the understanding of declaring and questioning intonation at the sentence-level. The rationale was to provide conditions that would be more representative of naturalistic conversational settings than those presented by the PEPS-C subtest. A further rationale for this experiment was provided by Relevance theory (Sperber & Wilson, 1995), which makes explicit predictions about individuals' levels of meta-representational ability and their corresponding capacity to understand different types of intention.

In this chapter, the children's total score from the receptive part of the PEPS-C test was used cautiously as an index of their level of meta-representational ability. The rationale for this is that the total receptive score from the PEPS-C test correlated positively with the British Picture Vocabulary Scale (BPVS) standardised score for both groups of children. Since there is considerable evidence to show that verbal intelligence level, as measured by standardised intelligence tests such as the BPVS or its equivalents, has a close correlational relationship with performance in theory of mind tests in children (Bowler, 1992; Cutting & Dunn, 1999; Dahlgren & Trillingsgaard, 1996; Eisenmajer & Prior, 1991; Happé, 1995; Jenkins & Astington, 1996; Ozonoff, Pennington, & Rogers, 1991; Tager-Flusberg & Sullivan, 1994; Yirmiya, Erel, Shaked, & Solomonica-Levi, 1998), this seemed justified. Furthermore, as studies have found an even closer relationship between higher-level language processing ability (i.e., semantics and syntax of sentential complements) and theory of mind task performance (de Villiers, 2000; Tager-Flusberg, 1997; 2000), than that between vocabulary knowledge and theory of mind task performance, some researchers have argued that theory of mind problems in autism might reflect limitations in their linguistic knowledge (de Villiers, 2000; Tager-Flusberg, 2000). It is difficult to postulate about the causality between language competence and theory of mind ability, as both age and verbal mental age have been shown to contribute to theory of mind performance in children with autism (e.g., Happé, 1995). Indeed, no individual with autism, with a verbal mental age of less than six years and chronological age of less than eight years has been found to succeed in theory of mind tests (Dahlgren & Trillingsgaard, 1996; Yirmiya, Solomonica-Levi, Shulman, & Pilowsky, 1996). However, although these abilities are inextricably linked, research has shown that there are individuals with autism with a greater verbal mental age than six years, and a greater chronological age than eight years, who have failed to pass theory of mind tasks (Kleinman, Marciano, & Ault, 2001). Thus, these factors cannot entirely account for this ability. Further arguments for using pragmatic language processing competence as an index of meta-representational ability is that traditional theory of mind measures have been criticised for their verbal nature and an explicit, artificial problem-solving format, which bear little resemblance to naturalistic social situations (e.g., Klin, 2000). Indeed, as some children with autism have been shown to pass theory of mind tasks of different levels of complexity, without showing corresponding levels of spontaneous social adaptation (e.g., Bowler, 1992; Dahlgren & Trillingsgaard, 1996), it has been questioned whether these individuals' social-cognitive capacities actually are qualitatively the same as the social skills of typically developing children of the same age. Even if it were the case that theory of mind abilities were qualitatively similar in autism and typical development, they are clearly insufficient in naturalistic social situations. Klin (2000) has outlined social skills that play an important role in social adaptation, but that are not required for succeeding in theory of mind tasks; these are the ability to actively seek social information in the environment; to discriminate between core and peripheral social information, and between relevant and tangential responses; and the ability to integrate social information into a social context giving rise to a given social situation (Frith, Happé, & Siddons, 1994; Happé & Frith, 1995; Klin, Schultz, & Cohen, 2000). A further criticism of the traditional theory of mind tests concerns their "all-or-nothing" nature, which disregards the dimensional rather than dichotomous nature of these abilities. Thus, whilst in this study, the total receptive PEPS-C score was used as a measure of meta-representational ability, it was acknowledged that children with autism are likely to possess variable degrees of pragmatic understanding. Indeed, Tager-Flusberg (2001a) has suggested that measures assessing pragmatic abilities provide a more sensitive index of individual differences in theory of mind abilities amongst children with autism, than do traditional theory of mind tasks. There is also evidence showing that communicative competence correlates strongly with false-belief understanding in children with autism (Capps, Kehres, & Sigman, 1998). The final rationale is that, in the light of the predictions of the developmentally focused componential model of theory of mind (Tager-Flusberg & Sullivan, 2000), a distinction is made between basic social-perceptual abilities and the later emerging higher-level cognitive-linguistic capacities, of which only the latter are measured by the traditional theory of mind tests. This theory rests upon the notion that theory of mind is a developmental concept, comprising several interacting mechanisms that are involved in the development of social information processing. Importantly, theory of mind abilities are not social-cognitive capacities that emerge fully developed at the age of four. The model emphasises the importance of early-developing perceptual abilities involved in the processing of mental state information, from eyes, faces, and voices. As such developments are ignored by the traditional social-cognitive theory of mind tasks, new measures have been developed to test the broader predictions of social cognition. Examples of such new tests include the eyes task (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997), the parallel voices task (Kleinman et al., 2001), and the social attribution task (Klin, 2000). These have been designed specifically to avoid the explicit and verbal problem-solving format that characterises many of the traditional tests. Tager-Flusberg (2001a) further notes that prosodic understanding reflects sophisticated social-perceptual abilities. As the PEPS-C test battery assesses prosodic abilities in a context where linguistic information-processing is kept to a minimum, it appears that performance in these subtests may tap into the social-perceptual component of theory of mind. As the social-cognitive component is assumed to build upon the developments in the social-perceptual domain, individuals with highly developed social-perceptual abilities can then be expected to be less impaired in social-cognitive competence, including language. Thus, the current study will examine the relationship between social-perceptual prosodic abilities, and higher-level cognitive-linguistic abilities. As the focus of this chapter is on the broader concept of theory of mind, mentalising capabilities will be referred to as "social-cognitive" or "meta-representational" abilities, rather than "theory of mind" abilities.

Of relevance here is a study carried out by Klin (2000), which focused upon the relationship between theory of mind task performance and "real-life" social cognitive abilities in individuals with autism, Asperger syndrome, and typical development. Although all participants had passed a second-order theory of mind test, the individuals in the autism groups nevertheless showed considerably impoverished social adaptation skills, as measured by the Vineland Adaptive Behavior Scales (Sparrow, Balla, & Cicchetti, 1984). The experimental paradigm was a social attribution task adapted from Heider and Simmel (1944), where the participants were required to produce narratives in response to the silent cartoon animation in which geometric shapes engage in interaction. A coding system was devised whereby the participants' responses were rated on six indices, each of which related to different aspects of social-cognitive competence. For example, the theory of mind indices measured the frequency with which participants used cognitive mental state terms in their narratives, and the salience index assessed the readiness with which the participants made social attributions to the ambiguous visual stimuli. The data analysis showed that this paradigm enabled the reliable identification of marked social cognitive deficits in intellectually able individuals in the autism groups. Interestingly, these deficits were unrelated to their verbal intelligence and linguistic skills. Strikingly, these individuals were sensitive to only 25 per cent of the social features in the cartoon. More specifically, a third of their attributions were socially irrelevant to the material presented in the video, and they used considerably fewer relevant affective and cognitive mentalistic terms than did their controls. Furthermore, the participants in the autism groups failed to construct psychological personality attributes on the basis of the characters' actions. Intriguingly, when the participants were tested in a more verbally explicit question-answer version of the task, where some of the social features of the cartoon were explained, even the participants with Asperger syndrome still showed significantly poorer performance than the controls. In summary, the findings of this study showed that whilst second-order theory of mind ability, as measured by the traditional tests, is necessary for social understanding, it is by no means a sufficient index of real-life social adaptation in autism. An important next step, therefore, is to examine the role of social-perceptual abilities (e.g., prosody), in social-cognitive understanding.

As was discussed in the introductory chapter of this thesis, research into theory of mind abilities in autism has noted particular difficulties with self and other mental state attributions (Baron-Cohen, Leslie, & Frith, 1985). It has been suggested that the representation of mental states requires meta-representational ability (Leslie, 1987; 1988). A core component of Relevance theory (Sperber & Wilson, 1995) is that the ability to attribute intentions to others is a fundamental characteristic of human communication (p.23). It thus follows that impaired meta-representational abilities in autism would manifest as an inability in such individuals to use language for communication. This will be considered in more detail below.

Sperber and Wilson (1995) define communication as "putting one's thoughts into words" (p.1). They further suggest that as sentences can express a nearly infinite number of different thoughts, the semantic representation of sentences can only be regarded as a poor description of the speaker's thoughts. The gap between thoughts and semantic utterances contains inference and pragmatics; therefore the comprehension of an utterance is an inferential process. Intimately related to this inferential process is the context within which utterances are interpreted, including the listener's beliefs about the mental state of the speaker. According to Sperber and Wilson (1995), "communication is successful not when hearers recognise the linguistic meaning of the utterance, but when they infer the speaker's "meaning" from it" (p.23). Thus, utterances carry two types of intention; an informative type, which informs the listener about something; and the communicative type that informs the listener about one's intention to inform. Intention, of course, is a psychological state, and it is vital that the listener is capable of mentally representing the speaker's intention in order to understand his/her communicative intention. As Relevance theory specifically states that the understanding of the literal or informative intention is a first-order process, whilst the comprehension of communicative intention is a second-order intention (intention about a person's mental state), it would follow that individuals with first-order meta-representational ability would only understand the literal meaning of an utterance, and that such individuals would fail to recognise the communicative intention of the utterance, as second-order meta-representational ability is required. It may then be the case that, in autism, the understanding of a communication would break down precisely at the point where the literal meaning of an utterance would need to be adjusted for the speaker's intention. Indeed, evidence for this postulation has been reported in a study by Happé (1993), where the level of meta-representational ability of children with autism was directly related to their ability to understand utterances expressing simile, metaphor and irony. This study was thus set to test the basic predictions of Relevance theory. The stimuli comprised three levels of difficulty, each predicting increasing level of theory of mind ability: similes, which can be understood at the literal level, and thus require no meta-representational ability; metaphors, which, on the other hand, require some understanding of intention (first-order theory of mind); and finally, ironic utterances, which require second-order meta-representational ability, as their literal meaning contradicts their communicative intention. The findings showed that the level of meta-representational ability of the children directly predicted their communicative competence: the children with second-order meta-representational ability showed higher levels of performance in all three conditions compared with children with no theory of mind, and with first-order theory of mind ability only. These children were also the only group to be able to understand irony. The children with first-order theory of mind ability were able to understand similes and metaphors, whilst the children with no theory of mind ability were only able to understand similes. Thus, the results confirmed the predictions of Relevance theory by showing that the degree of meta-representational ability predicted the degree of communicative competence of the children. Furthermore, in the light of the findings from the affect input subtest of the PEPS-C test battery, some indication that children with autism showed a difficulty with understanding the communicative intention of the utterances (i.e., the speaker's affective state) was seen.

Relevance theory further assumes that human information processing is largely driven by relevance, that is, individuals automatically process information that is relevant to them. A further characteristic of this process is that it aims at achieving maximum relevance with minimum cognitive effort. Evidence showing that the salience of socially relevant stimuli is substantially reduced in autism (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Klin, 1991) strongly suggests that information recognised as "relevant" by individuals with autism is likely to differ from what is considered as such by those with typical development. It may also be the case that speech in general is less relevant for many individuals with autism throughout all developmental periods. Indeed, it should be noted that approximately half of the autistic population fail to acquire functional language during their life-time (Bailey, Phillips, & Rutter, 1996). Experiment three, reported in chapter three, found that when given a choice to either attend to the perceptual (pitch contours) or semantic aspects of sentences, children with autism chose to respond to the semantic content significantly more often than to the perceptual features of the speech stimuli, although their semantic speech processing bias was significantly weaker than their controls. Thus, this is more a question of degree of neglect rather than of absolute failure to attend to speech normally. Although experiments one, two and four found that children with autism showed significantly enhanced processing of pitch contours in speech compared to their controls, the findings from experiment three suggested that the semantic content might have carried relatively higher relevance for them than the perceptual aspects in speech. Thus, the current experiment will test whether this "relevance" is sufficient to have enabled the development of pragmatic skills in children with autism, as was indeed suggested by the results from the turn-end type input subtest of the PEPS-C battery. Sperber and Wilson (1995) suggest that relevance guarantees efficient information processing due to the fact that all human intentional communication is ostensively providing evidence of one's thoughts. Thus, a subtle test would be the ability to discriminate between ostensive and non-ostensive communication in individuals who have difficulties in representing the thoughts, or the intention, of the speaker. A speaker who generates an ostensive stimulus has two intentions: firstly, the informative intention, and secondly, the communicative intention, to make one's informative intention mutually manifest for the speaker and the listener. It is specifically this ostension that aids the hearer to focus on the relevant aspects of information in an utterance. It thus follows that the recognition of intention behind an ostension is vital for efficient information processing, as a failure to do so would result in the listener missing out on relevant information. Indeed, this was demonstrated in the study by Happé (1993), showing that children with no theory of mind ability failed to understand the intention behind metaphoric and ironic utterances, and children with first-order theory of mind only missed out on this vital information in irony. Furthermore, with ostensive communication, the intended communicative effect is the understanding of the informative intention, and the intended communicative effect cannot generally be inferred until after the underlying informative intention has been established. Thus, in order to successfully understand communication, the inference process requires parallel processing of the informative and communicative intention.

In the experiment to be presented in this chapter, children with autism will be tested on their ability to process ostensive stimuli, where the communicative intention is achieved by the use of intonation. In order to make predictions about their performance in this task, the processing steps required for the understanding of interrogative and declarative utterances proposed by Relevance theory will be considered. According to Relevance theory, "verbal communication proper begins when the speaker is recognised not just as talking,... but as saying something to someone" (Sperber & Wilson, 1995, p.178). It follows that in most cases, the first stage of the interpretational process of an utterance is based upon its semantic properties. However, in cases such as the one to be tested in the experiment reported below, the semantic properties alone will not produce an appropriate interpretation for the reason that the communicative intention is produced perceptually, via intonation. However, Relevance theory further assumes that perceptual mechanisms are relevance-oriented, that is, the rising intonation of questioning utterances should be recognised as pragmatically relevant by the listener. Thus, the listener's task involves a series of subtasks, of which the first concerns the assignment of the correct intentional form to the utterance, which is that intended by the speaker. This involves the disambiguation of the utterance on the basis of its semantic and grammatical characteristics. As this step only involves disambiguating the semantic representation corresponding to informative intention, it can be predicted that children with autism with sufficient semantic processing ability will be able to compute the literal meaning of the sentences. However, semantic representations are ambiguous for the reason that they do not contain communicative intention, and in the best situation, can only very vaguely correspond to the speaker's thoughts. The process for assigning intentional form, however, is inferential, as the semantic representation needs to be adjusted for the communicative intention. Moreover, the expression of the intentional form in an utterance is more than explicit, in that it is further expressed by a certain "linguistically determined mood" (Sperber & Wilson, 1995). In other words, if an utterance has a falling intonational contour, it is uttered in a declarative form, and is a case of "saying that". By contrast, if an utterance is said with a rising intonation, it is uttered in a questioning mood, and thus is "asking whether" (Ibid, p.180). Thus, the mood of an utterance determines the intentional form expressed, and it is vital that the listener is able to appreciate whether, for example, information is being requested from him/her, in order to communicate appropriately. It then follows that if the children with autism are unable to represent the speaker's intention, in other words, recognise the speaker's intentional form from the "mood" or intonational contour of the utterance, it can be predicted that they will fail to understand that questioning utterances are often uttered with a rising intonation. As this study will use a forced choice design, requiring the children to classify utterances as questions or statements with no third response option, it is hypothesised that semantically able children with autism will assume, failing to understand their communicative intention, that most of the questioning utterances are declarative, on the basis of their informative intention only. By contrast, it is predicted that less linguistically able children will show random response patterns. It is further predicted that a good general receptive prosodic ability, as measured by the total input score of the PEPS-C test, will relate to good understanding of the communicative intention behind rising intonation in the questioning utterances in the children with autism. As has been mentioned previously, on the basis of experiment three, the semantic processing measures used in experiments two and five, it will be further predicted that children with autism with high verbal intelligence will be able to derive the literal meaning of utterances, and thus their informative intention. This preserved ability might bias them to interpret questioning sentences as declarative utterances, as for the children with relatively good language ability, the extraction of the informative intention should be easy.

A further rationale for the current study comes from the findings of experiments one, two, and four, which examined the processing of pitch contours across speech, speech-like, and musical stimuli. The findings invariably showed significantly superior pitch processing in the speech domain in children with autism compared with their matched controls, together with significantly compromised processing of speech for meaning, in experiment two. As these studies have effectively assessed the ability to process the perceptual features of intonational forms, it was therefore of interest to further examine the understanding of the communicative function of intonational forms. It is particularly difficult to understand how, in autism, semantic deficits reported in experiments two and five could co-exist with the intact pragmatic understanding suggested by findings of the turn-end type input subtest, as pragmatic processing is a higher level process still. That is to say that when the processing of the semantic content of speech has been tested separately from prosodic cues (i.e., in experiments two and five), the meaning of the sentences has been significantly worse understood by the children with autism than their matched controls. The investigation to be described in this chapter was carried out in such a way that the declaring and questioning utterances were of comparable length, and thus presented roughly equal processing demand, to the stimuli used in previous investigations. A paradigm developed by Patel, Peretz, Tramo, and Labreque (1998) was adopted. Here, all stimuli were sentences of three to 10 words in length, thus allowing the linguistic function of intonation to be examined in a more ecologically valid conversational setting than is provided by the turn-end type input subtest of the PEPS-C battery.

It is of relevance here to consider the findings of studies that have examined the understanding of declaring and questioning intonational patterns in individuals with autism. Firstly, in the expressive domain, an experiment by Fosnot and Jun (1999) assessed the ability of four children with autism to produce questioning and declaring intonation by reading pairs of short sentences, which either finished on a full stop or a question mark. The results showed that, relative to the performance of the control children with typical development and with a stutter, the children with autism failed to make a distinction between questions and declarative utterances, and made all sentences sound declarative. In the receptive domain, an electrophysiological study by Erwin, Van

Lancker, Guthrie, Schwafel, Tanguay, and Buchwald (1991) tested eleven high-functioning adults with autism and age-matched normal adults on their ability to perceive questioning and declaring utterances at the single-word level. The results showed that the auditory discrimination of such utterances was not deviant at the neural level in autism, thus supporting the behavioural findings of the turn-end type input subtest obtained from children with autism of variable levels of functioning, employing comparable stimuli. However, this finding should be interpreted with caution due to the fact that it included a small number of adults with high-functioning autism, and therefore might not generalise to children, either with or without co-occurring language difficulties.

METHOD

Participants

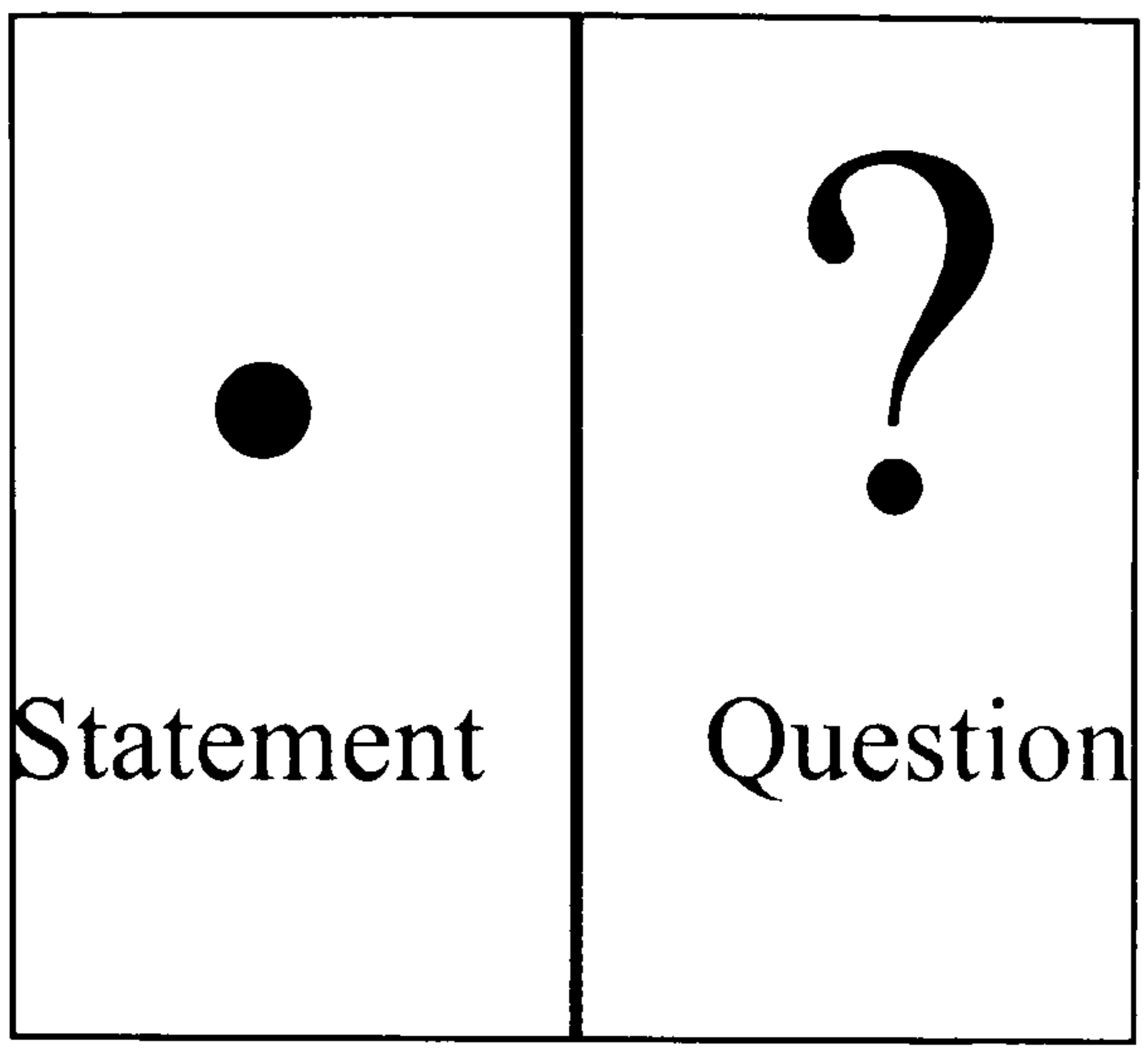
Seventeen male and three female children with autism, the majority of whom had participated in experiment three, were tested. They attended a specialist educational establishment for children with autistic spectrum disorders. Their ages ranged from 7 years, 4 months to 16 years, 3 months (mean 12 years, *SD* 2.27), the children's standardised scores on the British Picture Vocabulary Scale (BPVS) varied from 42 to 135 (mean 87, *SD* 23.67), and their raw scores on this measure varied from 56 to 142 (mean age equivalent 9 years, 7 months, *SD* 25.68). Fourteen male and six female control children were matched on the basis of age and standardised BPVS score to the children with autism. These children were recruited from three different schools: a mainstream primary school (10 children), a primary school for children with moderate learning difficulties (three children), and a secondary school for children with moderate learning difficulties (seven children). The children were aged from 7 years, 6 months to

16 years, 1 month (mean 11 years, 9 months, *SD* 2.61). Their standardised scores on the BPVS ranged from 44 to 124 (mean 86, *SD* 23.26), and their raw scores on this measure varied from 66 to 129 (mean age equivalent 9 years, 7 months, *SD* 21.11).

Test stimuli

Twelve English sentences, taken from Patel et al. (1998), were recorded twice so that the sentence pairs were lexically identical but differed in prosody. For example, a sentence "He wants to leave now" was first read as a statement and then as a question. A native English speaking male uttered all the sentences. The sentences were treated acoustically as documented by Patel and colleagues, with the sentence-question pairs modified so that they had the same syllable timing and amplitude patterns, resulting in sentence pairs in which fundamental frequency remained as the sole salient cue for discrimination. Two steps were taken, using the Praat speech editor (Boersma, 2001): (1) Duration of the final word was equalised; this word always carried the rise or fall in pitch. (2) As the words bearing rising intonation had higher amplitudes and so appeared louder, the amplitudes of the final words were equalised. A response slide shown in Figure 7.1 was constructed. The order of the 24 sentences was randomised, and the stimuli were presented as a PowerPoint presentation.

Figure 7.1 Response slide used in experiment six



Procedure

Each child was tested individually in a quiet room at their own school. The experimenter told the child that s/he was going to hear some sentences some of which sounded as if the person speaking was asking a question from the child, and some of which sounded as if the speaker was just making a statement or telling what is happening. In order to ensure that s/he understood what questions and statements meant, the response slide was shown to the child and the experimenter requested the child to ask something that s/he would like to know about her. The experimenter then asked the child to tell something that had happened in the classroom earlier. The experimenter then asked the child to comment on the differences between the two types of utterances. The stimuli were then presented on the laptop computer, and the child was told to categorise each sentence. No feedback was given and the experimenter recorded the child's responses.

RESULTS

The means, standard deviations, ranges, and percentages for correct categorisation of declaring and questioning utterances for the children with autism and their controls is displayed in Table 7.1.

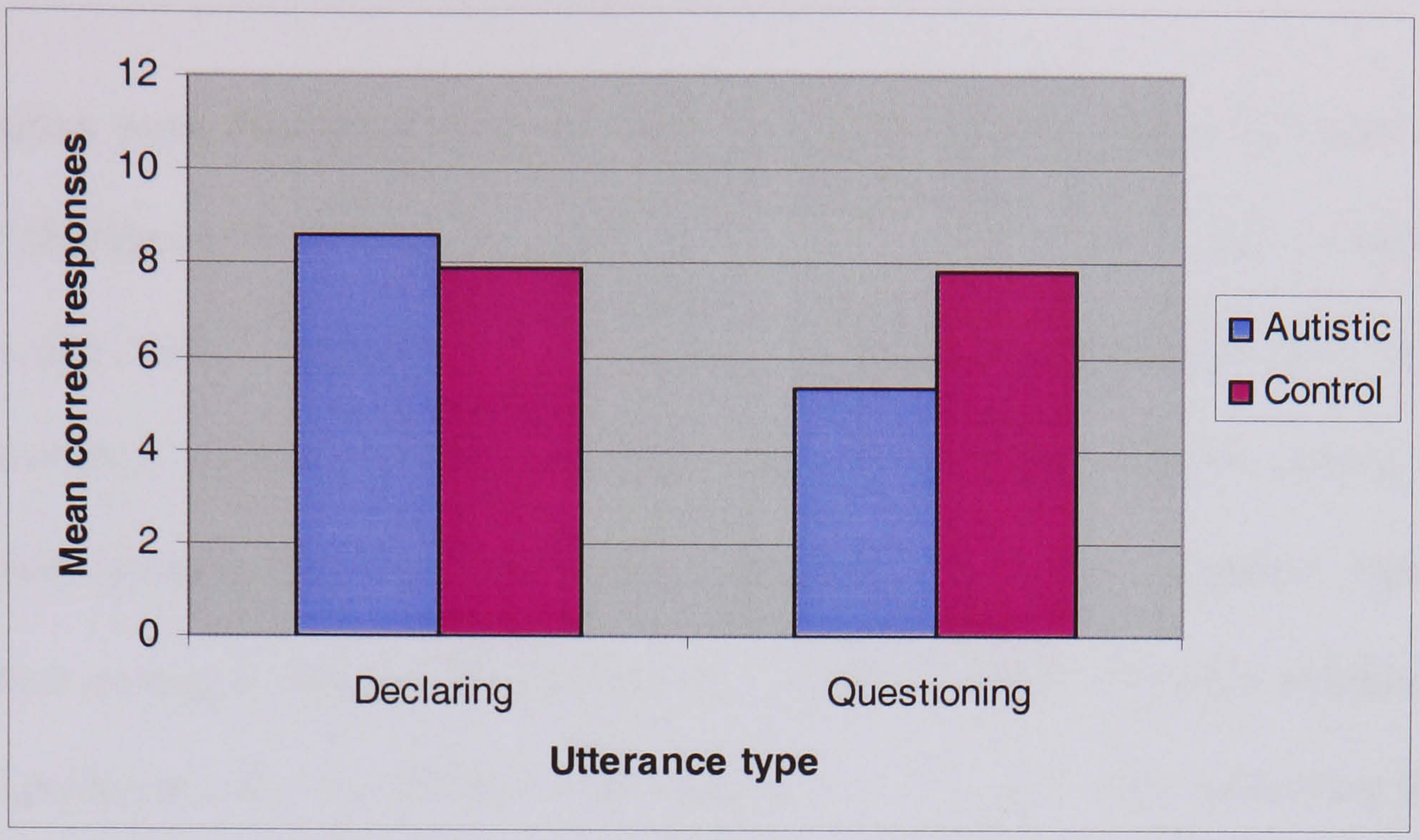
Table 7.1 Means, standard deviations, and ranges for the correct identification of declaring and questioning utterances (% correct in parentheses) for the children with autism and their controls

	Declarative utterances			Question utterances		
	Mean	SD	Range	Mean	SD	Range
Autism group (N=20)	8.60 (72%)	3.28	2-12	5.35 (45%)	2.80	1-12
VIQ- and age-matched controls (N=20)	7.85 (65%)	3.12	2-12	7.90 (66%)	2.13	5-12

*Maximum score per category = 12

In order to explore group differences in performance, a two-way analysis of variance was performed on the data, with utterance type (declarative/question) as the within-group factor, and diagnosis (autistic/control) as the between-group factor. This analysis revealed a significant main effect of utterance type (F (1, 38) = 5.02, $p < .04$), with more declarative utterances being correctly classified overall. The main effect of diagnosis (F (1, 38) = 2.61, n.s.) failed to reach significance, but a significant utterance type by diagnosis interaction emerged (F (1, 38) = 5.34, $p < .03$), as illustrated in Figure 7.2.

Figure 7.2 Mean number of declaring and questioning utterances correctly identified by the children with autism and their matched controls



*Maximum score per condition = 12

In order to explore the interaction further, two sets of t-tests were carried out on the data. This analysis revealed that the control children were significantly better at recognising question utterances than their autistic counterparts (*t* (38) = -3.25, *p* < .005), whilst no group differences emerged for the classification of declarative utterances (*t* (38) = .74, n.s.). Paired samples t-tests revealed a significant condition effect within the autism group (*t* (19) = -2.80, *p* < .02), with better performance occurring for the identification of declarative utterances. No significant condition effect emerged for the children in the control group (*t* (19) = .06, n.s.), indicating that these children showed equal levels of performance in classifying declarative and question utterances. Table 7.1 shows that the range of scores for the children with autism in the question category is wider than that of their matched controls, indicating that some children with autism made a low number of question judgements of the stimuli. Thus, these findings supported the prediction that children with autism would show particular difficulties with associating rising intonation with question utterances.

Correlations were then performed between age, psychometric, and experimental data. For the children with autism, this analysis revealed a significant negative relationship between the correct classification of statement and question utterances (r = -.45, p < .05), providing support for the prediction that children with autism would fail to understand prosodically cued question utterances. A further negative significant correlation emerged between the performance in the question utterance condition and verbal intelligence for the children with autism (r = -.51, p < .03), indicating that the declarative bias was stronger in more verbally able children with autism than in those with lower verbal ability. All other correlations for the children with autism failed to reach significance. For the control children, good performance with the declarative utterances was associated with good performance with the question utterances (r = .48, p < .05), indicating that these children made correct classifications of the two types of utterances in a balanced fashion. All other correlations for the control children failed to reach significance.

As the hypothesis specifically stated that children with autism would make more declarative classifications of the utterances overall, reflecting their inability to understand communicative intention, total numbers of declarative and question judgements made by the children within both groups were calculated, and converted into percentages. This analysis is not concerned with accuracy, but simply with data distribution. Table 7.2 displays the proportion of declarative and question judgements out of the total number of judgements made by the children with autism and their controls.

Table 7.2 Proportion of declarative and question judgements from the total number of judgements made by the autism and control groups

	Declarative	**Question**
Autistic N=20	64%	36%
Control N=20	50%	50%

Table 7.2 shows that whereas the control children performed in an unbiased fashion, the children with autism exhibited a marked declarative bias, supporting the hypothesis stated above.

The frequencies of children making certain numbers of declaring and questioning judgements of the stimuli were then calculated. Table 7.3 displays the clusters of children in percentages within each group making zero to six, seven to 12, 13 to 18, and 19 to 24 judgements in total within each utterance type category. As each child made a total of 24 judgements, the cluster categories that represent non-biased response patterns are shown in bold italics.

Table 7.3 Clusters (in %) of children with autism making certain total numbers of declarative and question judgements of the stimuli, presented alongside control data

	Declarative judgements				**Question judgements**			
Total number of judgements made	**0 to 6**	***7 to 12***	***13 to 18***	**19 to 24**	**0 to 6**	***7 to 12***	***13 to 18***	**19 to 24**
	Proportion of children (%)				**Proportion of children (%)**			
Autistic (N=20)	5	***25***	***35***	35	45	***30***	***20***	5
Control (N=20)	10	***25***	***65***	0	0	***70***	***25***	5

*Total number of judgements per child = 24

An inspection of the proportion of children in the clusters representing non-biased response patterns (shown in bold italics in Table 7.3) confirms the earlier observations that, whereas approximately half of the children with autism exhibited a marked declarative bias, approximately 90 per cent of the control children responded in an unbiased way to the stimuli. This was further illustrated in Table 7.2. This will be discussed further in the discussion sections of this chapter.

As Relevance theory allows specific predictions to be made about an individual's meta-representational ability and their communicative competence, the relationship between the children's prosodic-pragmatic ability, as measured by the PEPS-C receptive test battery, and their performance in the current experiment, was examined. This correlational analysis revealed that for the children with autism, a strong positive correlation emerged between prosodic-pragmatic ability and performance in the declarative utterance type category ($r = .83$, $p < .001$), suggesting that children with good prosodic-pragmatic ability made correct declarative classifications of the stimuli. This finding is in line with the earlier reported negative correlation between verbal ability and performance with the question utterances for the children with autism.

However, this result failed to support the prediction that children with autism with higher pragmatic ability would be better able to understand question utterances. All other correlations for the children with autism failed to reach significance. For the children in the control group, prosodic-pragmatic ability correlated positively with performance for the declarative utterances ($r = .55$, $p = .01$). Furthermore, pragmatic ability was associated with good understanding of question utterances ($r = .69$, $p < .001$), suggesting that the PEPS-C receptive score provided an index of pragmatic competence in the control children.

Finally, the performance within each group of children was compared against chance level performance (6) in both utterance type categories applying one-sample t-tests. This analysis revealed that for the children with autism, performance was significantly above chance in identifying declarative utterances (t (19) = 3.54, $p < .005$), whilst their performance in the classification of question utterances was at chance (t (19) = -1.04, n.s.). The children in the control group showed levels of performance that were significantly above chance in identifying both declarative (t (19) = 2.66, $p < .02$) and question utterances (t (19) = 4.00, $p = .001$). In chapter eight, the performance of children with good semantic processing ability will be compared against those with low semantic processing ability, in this task.

DISCUSSION

The results from experiment six, showing a significant declarative bias in autism, supported the prediction that children with autism would fail to understand prosodically cued, as opposed to syntactically cued questions. This finding further supports the predictions drawn from Relevance theory that children with autism with deficits in meta-representational ability would have difficulty in understanding the communicative intention conveyed by rising intonation. In contrast, the control children showed an extremely unbiased pattern of responding, with equal numbers of declarative and question judgements being made. Furthermore, these children made a balanced number of accurate declarative and question judgements. Correlational analyses showed that for the control children, good performance in one condition was also associated with competence in the other condition. As the controls were matched on chronological age and verbal intelligence, this finding reinforces conclusions that the inability to understand questions was very specific to the children with autism.

The finding that approximately 90 per cent of the control children showed an unbiased pattern of responding to the stimuli in comparison with approximately 50 per cent of the children with autism, was striking. A closer inspection of the distribution of the scores of the children with autism displayed in Table 7.3 revealed that 45 per cent of these children made zero to six question judgements, confirming that approximately 45 per cent of the children exhibited declarative bias. In other words, these children failed to recognise question utterances on the basis of their intonational contour. This finding is interesting in respect to findings from experiments one, two, three, and four, showing that the children with autism were significantly more proficient at processing pitch information in speech stimuli than their matched controls. This suggests that these children had a good perception of pitch, but nevertheless showed reduced understanding of its pragmatic function in speech. None of the control children showed a declarative bias in their responses. Surprisingly, with regard to the declarative utterance type, a greater proportion of the control children made zero to six judgements than the children with autism (10% versus 5% for the autism group; illustrated in Table 7.3), raising the possibility of a question bias in these children. However, as shown in Table 7.2, the majority of the control children responded in an unbiased fashion. These findings do however suggest that the two groups of children showed qualitatively different patterns of responding to the stimuli. It seems likely that these findings reflect impaired pragmatic understanding in the children with autism. This possibility will be considered below.

As this experiment was specifically set out to test the prediction made by Relevance theory that in order to understand communicative intention, second-order meta-representational ability is required, the children's performance was related to their general receptive pragmatic ability. Based upon the notion that measures assessing pragmatic competence provide a more sensitive measure of individual differences in theory of mind abilities amongst children with autism, than do traditional theory of mind tests (Tager-Flusberg, 2001a), the children's total receptive prosody score from the PEPS-C test battery was used as an index of meta-representational ability. A further rationale for using prosodic understanding as a measure of meta-representational ability was to test the predictions of the componential theory of mind model (Tager-Flusberg & Sullivan, 2000; Tager-Flusberg, 2001a), in which good prosodic understanding is assumed to reflect sophisticated social-perceptual abilities, and that, such abilities tap into higher-level social-cognitive understanding. Thus, this study enabled the relationship between social-perceptual abilities and higher-level social-linguistic understanding to be examined. Surprisingly, for the children with autism, prosodic ability, as measured by the receptive PEPS-C test battery, was strongly associated with a tendency towards a declarative bias (a correlation of .83). This finding failed to support the prediction that more pragmatically able children with autism would be able to understand the communicative meaning signalled by rising intonation in question utterances. A related finding was that showing a negative association between verbal intelligence and performance in the question utterance category, suggesting that more verbally able children displayed a declarative bias.

In the light of the componential model of theory of mind, the current findings suggest that social-perceptual, or prosodic abilities, as assessed by the PEPS-C receptive test battery, do not adequately measure higher-level social-cognitive abilities in autism. As higher social-perceptual, prosodic skills were associated with a declarative bias, these skills were not sufficient for understanding the pragmatic meaning conveyed by questioning intonation for the children with autism. By contrast, for the control children, high social-perceptual, prosodic abilities were associated with good discrimination of both declarative and question utterances, thus lending support to this model. Furthermore, the finding that this relationship was closer for the question utterances than declaratives also supported the prediction of Relevance theory that question utterances require higher levels of meta-representational ability than do declaratives, due to their involving the understanding of communicative intention. The finding that the more verbally and pragmatically able children with autism showed a particularly strong declarative bias suggests that these children are likely to have shown relatively good linguistic, and thus semantic processing ability. As verbal intelligence has correlated with semantic processing ability for children with autism in experiments two, three, and five, it can be expected that these children will be likely to process speech for meaning. However, an excessive focus upon the semantic information might have resulted in the majority of these children missing out on relevant perceptual, prosodic information, such as that conveyed by intonation. This finding confirms the earlier observations that pragmatic deficits are universal in autism (Lord & Paul, 1997; Wilkinson, 1998; Tager-Flusberg, 1999). Furthermore, as the more *verbally able* children with autism were more likely to display a strong declarative bias, this suggests that the less able children showed a more random pattern that was mistakenly viewed as a "balanced" pattern of responding. However, the findings from experiment six are in line with previous evidence reporting theory of mind deficits in autism (Baron-Cohen, 2000), which in the current study were reflected in the poor understanding of questioning intonation by children with autism. Findings further indicated that one outcome of these deficits was a bias towards assuming that utterances were declarative. Fosnot and Jun (1999) reported very similar findings in their study examining the expression of declaring and questioning intonation in children with autism.

As prosodic ability was not associated with good performance for the question utterances in the group of children with autism, this raises questions about the representativeness of the PEPS-C receptive score as an index of "real-life" pragmatic ability. Rather, on the basis of the current findings it might be suggested that the PEPS-C subtests tap into the social-perceptual component of theory of mind rather than into the higher-level social-cognitive component. Indeed, as was mentioned previously, prosodic abilities are assessed in a context where minimal linguistic processing is required, and natural communicative contexts rarely present themselves in such a fashion. The findings from experiment six, however, do show parallels to those reported in studies that have examined the relationship between children's performance in traditional theory of mind tests with real-life social adaptation (e.g., Klin, 2000): whereas prosodic abilities, as measured by the receptive PEPS-C test battery, may be necessary for social-cognitive understanding, they are not sufficient for spontaneous pragmatic competence in naturalistic conversational settings for children with autism. Possible explanations for the discrepancy between the children's performance in the PEPS-C test battery and experiment six concern differences in the nature of the tasks. Whereas the PEPS-C test battery aims at assessing children's pragmatic-prosodic abilities in a context where other forms of linguistic processing demands are kept to a minimum, the current experiment examined the children's understanding of the pragmatic meaning of intonation in context where the stimuli were full sentences, and thereby more representative of natural conversation. It might be that verbally able children with autism were able to "hack" out solutions (Happé, 1995; Happé, Ehlers, Fletcher, Frith, Johansson, Gillberg, Dolan, Frackowiak, & Frith, 1996; Klin et al., 2000) to the PEPS-C stimuli, using verbal and general problem-solving skills rather than their pragmatic knowledge, thereby appearing as competent as some of the control children in pragmatic understanding. However, these abilities did not correspond to "real-life" abilities, especially when parallel processing of semantics and pragmatics was required. As was mentioned before, these findings suggest discrepancies between the basic social-perceptual abilities and social-cognitive competence in autism. However, such inconsistencies are unsurprising given the atypical language trajectory in autism, whereby language development is significantly delayed, and the salience of social information early on in development is reduced (see Klin, Jones, Schultz, & Volkmar, 2003), resulting in fundamental impairments in social-perceptual abilities (Tager-Flusberg, 2001a). Furthermore, the results from experiment six are very important as they suggest that a test assessing the ability to understand questioning utterances at the sentence-level might provide a sufficiently sensitive way of identifying pragmatic deficits in individuals with autism, who show otherwise high levels of cognitive functioning.

There is anecdotal evidence from some verbally able children with autism, who showed a strong declarative bias, to suggest that in some ways their speech processing was strikingly more mechanical and inflexible than that seen in typical development. Many of these children told the experimenter that none of the stimuli included "Wh" question words (why, what, when, where, etc.), and were therefore not questions. It is of relevance to note that social skills training in autism can include the learning of "scripts" (e.g., Mesibov, 1986), that result in verbally able children with several such scripts appearing socially competent. Whilst this type of mechanical learning can enable children with autism to understand linguistically cued questions, that is, for example, utterances containing "Wh" words or sentence structures including "Do you…", scripts are relatively ineffective for prosodically cued questions. The difference being that, whereas linguistically cued questions can be understood at the literal level by performing a simple syntactic-semantic computation, prosodically cued questions can only be understood if the listener can appreciate the speaker's communicative intention conveyed by intonation (Sperber & Wilson, 1995). Thus, prosodically cued questions present significantly greater information-processing demands, requiring finely tuned social meta-representational abilities. Furthermore, it has been noted that a major problem with the "scripts approach" is that it rarely generalises to novel social situations (Klin & Volkmar, 2000). It has frequently been proposed that the underlying difference between intellectually unimpaired children with autism and those with typical development concerns a reduction in the typical salience of social stimuli in autism (e.g., Dawson et al., 1998). It has also been suggested that such children's developmental pathways are focused upon a range of physical stimuli (Mottron & Burack, 2001). This developmental trajectory could therefore explain why, in autism, there is a greater specialisation in physical objects and features, than in social stimuli (Klin et al., 2003). This argument has been supported by evidence showing, for example, that in eye-tracking experiments of complex social situations, individuals with autism fail to focus on the eye-region of the person's faces, as would typical individuals, but instead, tend to focus upon the mouth region or to the peripheral regions away from the face (Klin, Jones, Schultz, Volkmar, & Cohen, 2002b). In the studies described in this thesis, the focus has been on testing the ability of children with autism to process the perceptual levels of speech. Taken together with the current findings, it is clear that these children show marked difficulties in understanding the social-communicative significance of such perceptual, prosodic cues.

In the next section, the current findings will be directly compared with those obtained from the PEPS-C turn-end type input subtest. Whilst both studies employed analogous paradigms, the crucial difference concerned stimulus length: whereas the turn-end type input subtest tested the children's ability to understand rising and falling intonation at one-word level, experiment six extended these findings to more naturalistic conversational stimuli.

COMPARISON OF DATA FROM EXPERIMENT SIX AND THE TURN-END TYPE INPUT SUBTEST OF THE PEPS-C

As a number of the same children participated in experiment six as had previously completed the PEPS-C test battery, it was of interest to compare the patterns of performance of the children with autism and their matched controls across the two studies. It was of particular importance to perform these comparisons as, whilst experiment six investigated the understanding of intonation at the sentence level, the turn-end type subtest did so at the single-word level only. Therefore the influence of information-processing demand in the two studies was examined in relation to children's performance. The results from these studies contradicted each other: whilst no significant differences in performance between the children with autism and their controls emerged in the turn-end type input subtest, experiment six showed that, whilst both groups showed equal performance in classifying declarative utterances, children with autism were significantly poorer at recognising questioning intonation, thereby displaying a marked declarative bias. It was thus of interest to probe these differences further. Especially, as in chapter six, the turn-end type input data was analysed as a single score comprising of both declarative and question judgements, it was of importance to examine whether this data analysis might have masked vital differences in patterns of responding between the two groups of children.

RESULTS

In order to perform the comparisons between the two sets of data, each individual child's turn-end type input score was divided into two separate scores: the correct identification of declarative and question utterance types. These children's age and psychometric data have been reported previously in Table 6.1. The means, standard deviations and ranges for the correct classification of declarative and question utterances in the turn-end type input test for the children with autism and their matched controls are shown in Table 7.4. The percentages of correct responses are shown in parentheses. The corresponding information for the data from experiment six is given in Table 7.1.

Table 7.4 Means, standard deviations, and ranges (% correct in parentheses) for the correct identification of declarative and question utterances in the turn-end type input test by both the children with autism and their matched controls

	Declarative utterances			Question utterances		
	Mean	**SD**	**Range**	**Mean**	**SD**	**Range**
Autism group (N=21)	5.81 (73%)	3.20	0-8	5.24 (66%)	3.22	0-8
VIQ- and age-matched controls (N=22)	5.36 (67%)	3.16	0-8	7.14 (89%)	1.28	4-8

*Maximum score per category = 8

The data were subjected to a two-way analysis of variance, with utterance type (declarative/question) as the within-group factor, and diagnosis (autism/control) as the between-group factor. The results showed that the main effects of utterance type (F (1, 41) = .89, n.s.), and diagnosis (F (1, 41) = 1.55, n.s.) failed to reach significance. Utterance type by diagnosis interaction was approaching significance (F (1, 41) = 3.39, p = .07). However, although the analysis of variance failed to reveal any significant differences in the performance between the two groups, the hypothesis specifically stated that children with autism would show deficits in understanding the communicative intention behind rising intonation; thus, two sets of post-hoc t-tests were carried out on the children's mean performance scores. The criterion for statistical significance was set at .025. The independent samples t-tests revealed that, whilst both groups of children were equally competent at identifying declarative utterances (t (41) = .46, n.s.), the children in the control group showed significantly better performance compared with the children with autism, in recognising question utterances (t (41) = -2.56, p < .02). This result lent support to the experimental hypothesis stating that children with autism would show deficits in understanding communicative intention in question utterances. Paired-samples t-tests revealed that, whilst within the autism group, levels of performance were equal across the declarative and question utterance types (t

(20) = -.52, n.s.), within the control group, the children's performance was significantly higher in the question utterance type category than declarative category (t (21) = 2.66, $p < .02$). These findings will be discussed further in the general discussion.

Correlations were then carried out between age, psychometric, and experimental data. For the children with autism, a significant positive correlation emerged between the declarative utterance type and the level of verbal intelligence ($r = .50$, $p < .03$), indicating that children with higher verbal ability were again more likely to display declarative bias than those with lower verbal ability. Furthermore, there was a positive relationship between age and performance with the question utterances ($r = .57$, $p < .01$), suggesting that older children were better able to understand the communicative intention behind rising intonation than younger children. All other correlations for the children with autism failed to reach significance. Again, for the children in the control group, a significant positive relationship emerged between the declarative utterance type and the level of verbal intelligence ($r = .66$, $p = .001$), showing that verbally able children made more correct declarative judgements of the stimuli than those with lower verbal ability. This finding will be further discussed. All other correlations for the control children failed to reach significance.

As the hypothesis specifically stated that children with autism would make more declarative classifications of the utterances overall, reflecting their inability to understand communicative intention, total numbers of declarative and question judgements made by the children within both groups were calculated, and converted into percentages. Table 7.5 displays the proportion of declarative and question judgements out of the total number of judgements made by the children with autism and controls.

Table 7.5 Proportion of declarative and question judgements from the total number of judgements made by both the children with autism and their controls

	Declarative	**Question**
Autistic N=21	53%	47%
Control N=22	39%	61%

Table 7.5 shows that 53 per cent of the total number of judgements made by the children with autism were declarative, and 47 per cent were questions. Thus, the children with autism exhibited a less biased response pattern in this task compared to experiment six. By contrast, for the children in the control group, 39 per cent of the total number of judgements made were declarative, and 61 per cent were questions.

The frequencies of children making certain numbers of declarative and question judgements was calculated in order to identify any response biases. Table 7.6 displays the clusters of children in percentages within each group making zero to four, five to eight, nine to 12, and 13 to 16 judgements in total within each utterance type category. As each child made the total of 16 judgements, the cluster categories that represent non-biased response pattern are shown in bold italics.

Table 7.6 Clusters (in %) of children with making certain total numbers of declarative and question judgements of the stimuli, presented alongside the control data

	Declarative judgements				**Question judgements**			
Total number of judgements made	**0 to 4**	***5 to 8***	***9 to 12***	**13 to 16**	**0 to 4**	***5 to 8***	***9 to 12***	**13 to 16**
	Proportion of children (%)				**Proportion of children (%)**			
Autistic (N=21)	24	***33***	***19***	24	24	***47.5***	***9.5***	19
Control (N=22)	18	***73***	***9***	0	0	***55***	***27***	18

*Total number of judgements per child = 16

An inspection of the proportion of children in the clusters representing non-biased response pattern (shown in bold italics in Table 7.6) shows that, whereas just over half of the children with autism exhibited a balanced way of responding, 82 per cent of the control children responded in an unbiased way to the stimuli. However, in contrast to results from experiment six, here fewer children with autism displayed a declarative bias (24% versus 45%), and surprisingly, 19 per cent of the children showed a question bias. Table 7.6 further shows that 18 per cent of the control children exhibited a question bias in the turn-end type input subtest. This will be discussed further in the general discussion.

In order to examine the relationship between meta-representational ability, as measured by the total score from the receptive PEPS-C subtests, and the children's performance in the turn-end input measure, correlations were carried out. This analysis revealed that for the children with autism, prosodic-pragmatic competence correlated positively with the identification of declarative utterances (r = .50, $p < .03$) and with the identification of question utterances (r = .62, $p < .005$). As the correlation was stronger between the total PEPS-C input score and question utterance type compared with the declarative utterance type, this finding further supported the idea that receptive prosodic ability might reflect meta-representational abilities in autism. This is because good understanding of communicative intention expressed by intonation is specifically predicted to be reflected in high scores for the question utterance type by Relevance theory. All other correlations for the children with autism failed to reach significance. For the children in the control group, prosodic-pragmatic ability correlated positively with the correct classification of declarative utterances ($r = .82, p < .001$), and with the identification of question utterances ($r = .51, p < .02$). Interestingly, however, the correlation was stronger between the total PEPS-C input score and the performance with declarative utterance type stimuli than it was with questions, reflecting an inverted pattern to that obtained for the children with autism.

Due to the responses again involving simple binary choices, the categorisation of the utterances into declaratives and questions by both groups of children was checked against chance level performance (4) applying one-sample t-tests. This analysis revealed that, for the autism group, performance was significantly above chance for the correct identification of declarative utterances (t (20) = 2.59, $p < .02$). However, these children performed at chance in classifying question utterances (t (20) = 1.76, n.s.). For the children in the control group, performance was narrowly below chance level for the identification of declarative utterances (t (21) = 2.03, $p < .06$). However, these children showed levels of performance that were significantly above chance in correctly classifying question utterances (t (21) = 11.46, $p < .001$). Thus, strikingly, the groups of children showed inverted patterns of performance when identifying the two types of utterances.

Finally, correlations were performed between the data from experiment six, and that from the turn-end type input subtest of the PEPS-C battery. Seventeen children with autism, and 21 control children, participated in both studies. For the children with autism, the question utterance type score from the turn-end type input subtest correlated positively with the declarative utterance type score from experiment six ($r = .84$, $p < .001$), suggesting a mismatch in the understanding of the two types of intonation, that is, between utterances of different lengths. For the children in the control group, all correlations failed to reach significance, suggesting that although analogous, the task used in experiment six was qualitatively different to the turn-end type input subtest of the PEPS-C battery. These findings will be discussed further below.

GENERAL DISCUSSION

In the studies reported in this chapter, Relevance theory was used as a framework for elucidating how meta-representational ability might relate to children's understanding of communicative intention in utterances. More specifically, as the recognition of an utterance as a statement or a question, on the basis of its intonational contour, requires the listener to infer the speaker's intention, such process would rely upon second-order meta-representational ability according to Relevance theory. In the light of the binary choice paradigm used in the current study, second-order meta-representational ability was assumed to manifest in the correct identification of question utterances. By contrast, impoverished meta-representational ability was expected to manifest as an incorrect classification of questioning utterances as declarative. In other words, such a response pattern would suggest a failure to appreciate the speaker's intention expressed by the rising intonation, resulting in the listener erroneously classifying the utterance as a statement on the basis of its informative intention only.

The findings from experiment six, testing the ability to understand declaring and questioning intonation at the sentence level, were discussed before the data analysis of the turn-end type input subtest of the PEPS-C test battery. The turn-end type input subtest provided data from the same children in an analogous task that only differed in stimulus length: here, all utterances were single word food items. Thus, an analysis of the children's performance in these two comparable tasks was carried out in order to isolate any effects that might reflect differences between the information-processing loads presented by the two tasks, and the impact that they may have upon the children's meta-representational performance. Interestingly, these two studies produced inconsistent results. The findings from the turn-end type input subtest showed that, whereas the children with autism exhibited equal levels of performance with the declarative and question utterances, the control children showed significantly higher levels of performance with the question utterances in comparison to the declarative stimuli. Furthermore, these children showed ceiling level performance in correctly classifying the question utterances, and their performance was significantly above that of the children with autism in this condition. Both groups of children showed equal levels of performance with the declarative utterances. The ceiling level performance of the control children with the question stimuli suggest that these stimuli were much more easily interpreted than those used in experiment six, and it seems plausible to suggest that this enabled the children with autism to "pull up" their performance with the question utterances to a level that was comparable to their performance with the declarative stimuli. A further limitation of the PEPS-C test concerns the fact that there may have been too few stimuli per category to provide reliable data on the children's abilities. A related point is that, as the maximum score per utterance type category in this study was eight, statistical tests might not be sensitive enough to bring out significant differences in such data.

An important difference between the data from experiment six and that from the turn-end type input subtest of the PEPS-C concerns the performance of the control children. Whilst these children showed an unbiased pattern of responding to the naturalistic stimuli used in experiment six, 18 per cent of these same children exhibited a marked question bias in the turn-end type input subtest. It should be noted here that, again, 50 per cent of the control children were identified as having moderate learning difficulties. The finding that, for this group of children, verbal intelligence correlated positively with correct identification of the declarative utterances suggests that it was specifically the children with moderate learning difficulties who were likely to show a question bias. A possible explanation for this surprising pattern of results might concern the differences in the stimuli between the two studies. As the control children showed no confusing patterns of performance with the sentence-level stimuli, which was more representative of naturalistic conversational contexts than those used in the turn-end type subtest, it might be suggested that the single-word stimuli were perceived as too easy, artificial and/or ambiguous by the control children, resulting in the observed pattern of performance. By contrast, the children with autism who are known to have pragmatic deficits, perhaps failed to appreciate the "naturalness" of the stimuli used in experiment six, and showed relatively "normal" and balanced patterns of performance with the artificial stimuli. Indeed, the finding that more verbally able control children performed well with the declarative one-word stimuli suggests that these children showed good levels of performance in this task, whilst the less linguistically competent children with moderate learning difficulties assumed that most of the utterances were questions. This argument, suggesting that the stimuli used in the turn-end type input subtest might have been "artificial", whereas those used in experiment six were more linguistically "natural", might be supported by the correlational analysis comparing the children's performance across the two studies. Here, no significant correlations emerged for the control children, suggesting that these children showed different patterns of performance across the two stimuli. Interestingly, however, for the children with autism, an ability to recognise declarative utterances in experiment six was negatively associated with the ability to understand question utterances in the turn-end type subtest. This finding is interesting when considered from the perspective of Relevance theory, as it may suggest that pragmatic ability of the more verbally able children with autism was sufficient for understanding communicative intention at the one-word level, whilst this ability broke down with the more communicatively natural, longer stimuli, which presented a greater linguistic and pragmatic information-processing load. Further support for this suggestion comes from the correlation showing that, for the children with autism, overall pragmatic ability was more strongly associated with the understanding of question than it was with the understanding of declarative utterances in the turn-end type input subtest. Furthermore, there was a positive relationship between age and the ability to recognise question utterances for the children with autism. As age has been shown to contribute to theory of mind abilities in children with autism (e.g., Happé, 1995), it appears that the predictions made by Relevance theory with regard to the levels of meta-representational ability required for understanding informative intention (i.e., first-order meta-representational ability), and communicative intention (i.e., second-order meta-representational ability) were well supported by the data from the children with autism from the turn-end type input subtest. When the findings from experiment six are considered in the light of the results from the turn-end type input subtest, it seems plausible that the strong declarative bias shown by the children with autism specifically reflected additive linguistic and pragmatic deficits in these children. Taken together, these results bear great resemblance to those reported for the traditional theory of mind tasks (e.g., Bowler, 1992; Dahlgren & Trillingsgaard, 1996), as both suggest that, an ostensible meta-representational ability, as measured by success in certain tasks, does not correspond to real-life social-cognitive competence in natural settings in individuals with autism (e.g., Klin, 2000).

The finding that the children with autism with good pragmatic ability were able to infer the speaker's communicative intention at the single-word level but not at the sentence-level, whilst the control children showed good levels of performance with both stimuli, suggest that the "pragmatic ability" of the children with autism was qualitatively different from that of the control children. This is unsurprising given that abnormalities in social-cognitive abilities are diagnostic criteria for the disorder. As was mentioned in the discussion for experiment six, ostensible social abilities in individuals with autism are usually acquired by mechanical learning (Mesibov, 1986), rather than being intuitive. Indeed, Klin and colleagues (2003) suggested that, as the "foundational" experiences of children with autism are not within the social domain, social knowledge is constructed outside this domain. Further support for the argument that individuals with autism might be relying on different, non-social cognitive and linguistic abilities when confronted with social information comes from a PET scanning study. In this, Happé and colleagues examined the patterns of brain activation in adults with autism and Asperger syndrome and typical controls in response to solving a range of basic and advanced theory of mind tests (Happé et al., 1996). The findings revealed that the individuals with autism failed to show activation in the same regions of the medial frontal cortex as were activated in typical individuals.

The current findings may seem less surprising if they are considered in the context of Relevance theory. This theory assumes that perceptual processes are relevance-driven. It thus follows that meta-representational abilities rely on the perceptual bias towards socially relevant information, such as the recognition of a speaker's intention, which lies behind his/her intonational contour. Numerous studies have reported deficits in the ability to read the mind or mood in a voice amongst individuals with autism (Hobson, Ouston, & Lee, 1989; Loveland, Tunali-Kotoski, Chen, Brelsford, & Ortegon, 1995; Rutherford et al., 2002; but see Boucher, Lewis, & Collis, 2000). This is consistent with the current results showing that ostensive stimuli appeared significantly less "relevant" for the children with autism compared to their controls. This reduced "relevance" of social stimuli might manifest in autism at a very early age, for example, as a failure to orient to speech over other types of auditory stimuli (Dawson et al., 1998; Klin, 1991). Indeed, Dawson and colleagues (1998) established that children with autism showed particularly severe attentional deficits with social stimuli. As the findings from experiments one, two, three, and four indicated that children with autism showed significantly enhanced processing of linguistically meaningless pitch in speech as compared with their controls, this supported the notion that these orienting and processing deficits are predominantly social and pragmatic in origin. Indeed, the suggestion that the reduction in the salience of social stimuli in autism results in such individuals developing greater specialisations regarding physical objects and features than in the social domain (Klin et al., 2003) fits in well with the described pattern of findings.

One rationale for using pragmatic-prosodic competence as a measure of meta-representational ability concerned the core predictions of the componential theory of mind model (Tager-Flusberg & Sullivan, 2000; Tager-Flusberg, 2001a). More specifically, that prosodic skills reflect sophisticated social-perceptual abilities, and that such capacities form the foundation for later developments in the social-cognitive domain. Thus, a distinction is made between social-perceptual and social-linguistic abilities. The current investigation aimed at examining the relationship between these components in autism. It is interesting to note that the social-perceptual component is assumed to build upon the innate preference of infants to attend to human social stimuli (e.g., Mehler & Dupoux, 1994), resulting in rich data input from the social domain very early on in development. The finding that social-perceptual competence, as measured by prosodic understanding, did not correspond to good social-linguistic abilities in autism, is likely to reflect the down-stream effects of the atypical developmental trajectory in autism (Klin et al., 2003) that results in qualitatively different social-perceptual development. Subsequently, it is likely that the ceiling-level performance of some children with autism in the PEPS-C test battery reflected their use of verbal and other reasoning skills, to "hack" out solutions to these tasks (Happé, 1995; Happé et al., 1996), rather than "real-life" pragmatic abilities. The current findings suggest that, whilst the aspects of theory of mind measured by the PEPS-C test were sufficient for the understanding of communicative intention at the single-word level, this pragmatic ability, whilst necessary, was not sufficient for appreciating such intention at the sentence-level. This suggests that the children with autism did not possess second-order meta-representational abilities. Furthermore, findings from experiment six suggested that prosodic abilities as measured by the PEPS-C test may have reflected social-perceptual abilities that were qualitatively different in the children with autism, as compared to their controls. Furthermore, whilst the good performance of the children with autism in the PEPS-C test battery masked substantial pragmatic deficits, it was suggested that the test assessing the understanding of communicative intention at the sentence-level may be a sufficiently sensitive measure for identifying pragmatic deficits in individuals with autism.

A further explanation for the inconsistent pattern of findings across the two studies may concern the difference in the context in which the understanding of falling and rising intonation was examined. Whereas in experiment six, the children were required to indicate whether an utterance was a "statement" or a "question", the turn-end type used a framework involving someone "offering" some food versus "telling" what he sees in a book. It may simply be that the context employed by the turn-end type subtest was easier for the children with autism to understand than that presented in experiment six. It might be argued that it takes less effort to infer the speaker's mental state when it involves the mental state of "desire" or "wanting", as compared to a situation in which such contextual information is less explicit. Indeed, there is evidence to show that certain mental state terms are more easily understood than others by children with autism. For example, studies have reported that children with autism can predict behaviour and emotions on the basis of desire (Tager-Flusberg, 1992; Tan & Harris, 1991), whilst it has been found that individuals with autism show deficits in the understanding of cognitive or epistemic mental states (Sodian & Frith, 1994; Tager-Flusberg, 1992). In the light of experiment six, where no explicit information about the speaker's thoughts was provided, the children with autism may have failed to recognise the stimuli as ostensive communication. It thus follows that experiment six assessed the meta-representational abilities in a more cognitively demanding context than that of the turn-end type subtest.

Detailed data analyses identified similarities in the children's performance between experiment six and the turn-end type input subtest. Firstly, the control children showed significantly better understanding of the question utterances in both studies, as compared to the children with autism. Moreover, the performance of the children with autism with the question stimuli was at chance in both studies, whilst this was not the case for the control children. Secondly, children with autism showed a declarative bias in both studies; albeit less strongly so in the turn-end type input test, where the stimuli were more easily categorised. Intriguingly, however, clear qualitative differences between the performance of the children with autism and their matched controls were in evidence in both studies. Although it was found that 18 per cent of the children in the control group displayed a question bias in the turn-end type input test whilst performing in an unbiased fashion in experiment six, it is important to note that this bias was the reverse of that shown by the children with autism. Indeed, whilst the question bias implicates intact, although perhaps poorly tuned meta-representational function, the declarative bias shown by the children with autism indicated deficits in meta-representational abilities. In summary, as was discussed earlier, these qualitative differences most likely reflected differences in the developmental trajectories in autism and typical development, and more specifically, impairments in the early developing social-perceptual component of the theory of mind in autism.

Chapter Eight

What Is the Relationship between Perceptual Processing Abilities and Higher-Level Linguistic Competence in Autism?

Summary: In several of the experiments presented in this thesis, it has been noted that high levels of heterogeneity in performance in the perceptual, semantic, and pragmatic domains have been in evidence in the autism group. The question asked in this chapter concerns how semantic competence relates to the children's abilities in the perceptual and pragmatic domains, in two small subgroup samples of children with autism, formed on the basis of semantic competence. This was of special interest as previously reported experiments have failed to support the prediction of the weak central coherence hypothesis and the theory of enhanced perceptual functioning, that superior perceptual processing would occur at the expense of processing information for higher-level meaning in autism.

INTRODUCTION

The previously reported experiments that have examined children's ability to process speech for meaning have consistently found this to be considerably more heterogeneous in the children with autism than in their age- and intelligence matched controls. This chapter attempts to explore the characteristics of the children with good semantic processing ability further by comparing them to children with poor semantic processing ability, in psychometric and experimental task performance. The rationale for carrying out these comparisons is that the findings from experiments two, three, and five failed to support the experimental hypothesis stating that enhanced perceptual processing in autism occurs at the expense of processing speech at the semantic level. Thus, these results challenged the broad predictions of the weak central coherence (WCC) theory (Frith, 1989a; Happé, 1999) and the theory of enhanced perceptual functioning (EPF) (Mottron & Burack, 2001), as both suggest that autism is characterised by an information-processing bias in which local, perceptual-level information is processed at the expense of processing information for higher-level, global meaning. However, in experiments two and five, four types of subgroup performance were identified, of which only one processing style conformed to this hypothesis. The children in this subgroup showed good perceptual abilities that co-occurred alongside poor semantic processing. This finding suggests that the WCC and EPF theories may provide excellent frameworks for explaining subgroup performance in autism. In consequence, it is considered to be of interest to further examine the relationship between higher-level linguistic competence and low-level perceptual processing abilities in autism within subgroups.

Autism is a disorder that is diagnosed on the basis of behavioural features, and therefore involves a high degree of phenotypic and genetic heterogeneity. Recent research into autism has focused upon reducing the phenotypic variability in study samples by identifying subtypes within autism. This may have implications for specific patterns of neuropathology (Tager-Flusberg, 2004). Of particular relevance to the current study are the lines of research that have examined groups of individuals with autism sub-divided on the basis of different language profiles, and those that have compared children with autism against different cognitive profiles, where these profiles are based upon measures of social-communicative functioning. As was mentioned in the introduction to this thesis, one of the diagnostic criteria for autism is disordered language and communication (American Psychiatric Association, 1994). Furthermore, such deficits are often the earliest presenting symptom of the disorder, and are considered to be the most important predictor of both prognosis and developmental trajectory in affected individuals (Lord & Paul, 1997). Many of the earlier studies into language and communication impairments in autism concentrated upon identifying features that are universal and specific to the disorder (Tager-Flusberg, 1996). Such studies led to a consensus amongst researchers that the pragmatic deficits evidenced by a restricted range of speech acts (e.g., Loveland, Landry, Hughes, Hall, & McEvoy, 1988), and severely limited narrative and conversational abilities (Tager-Flusberg & Sullivan, 1995), in individuals with autism were a unique feature of the disorder, relative to other areas of linguistic functioning in autism and to children with other disorders (Baltaxe, 1977; see Lord & Paul, 1997; Tager-Flusberg, 1999; Wilkinson, 1998, for reviews). Pragmatic impairments have commonly been explained by, and related to, theory of mind deficits in autism. However, language abilities in this population are highly variable, and many individuals with an autistic spectrum disorder show marked deficits in their language that extend beyond pragmatic impairments. For example, whilst most of the children with autism show a significant delay in language acquisition, and indeed, a diagnosis of autism can only be given in the presence of this, there are children who develop vocabulary, as well as grammatical, and articulation skills that are within the normal range of functioning (Lord & Paul, 1997). On the other hand, approximately half of all individuals with autism fail to acquire functional language during their life-time (Bailey, Phillips, & Rutter, 1996). The question that has been addressed by recent studies concerns the broader language phenotype of autism, and here, subgroups with consistent, homogeneous patterns of abilities have been successfully identified. This line of research is of great importance due to the fact that most studies into language have treated individuals with autism as a single group, and focused upon group comparisons, despite the high degree of heterogeneity in such abilities. The question to be asked in this chapter concerns whether perceptual processing abilities may distinguish verbal, semantically competent children with autism from other verbal children, who show an impoverished ability to process speech for meaning. Previously reported studies have addressed the question of whether there are mean differences between perceptual and speech processing abilities in autism when compared to matched control children. Such differences have indeed been identified in both the semantic and pragmatic areas of speech, together with atypical perceptual abilities in the speech domain. The main rationale for the current study is derived from investigations of individuals with specific language impairment (SLI), which have suggested that impaired auditory processing abilities may be fundamental to such individuals' language impairment (Bishop & McArthur, in press; Tallal, 2000). It is thus interesting to wonder whether auditory discrimination abilities in autism may be related to such individuals' linguistic skills.

In one subgroup study, Kjelgaard and Tager-Flusberg (2001) studied the language abilities of 89 verbal children with autism between the ages of four and 14 years. A number of different language measures were administered, testing phonological abilities, receptive and expressive vocabulary, nonsense word repetition skills, and higher-level expressive and receptive semantic, syntactic, and grammatical abilities. The sample varied considerably in levels of intelligence, and due to the limited cognitive abilities of some children, approximately half of the individuals in the sample were unable to complete the higher-level language tasks. The standardised scores for each of the tests indicated that the language skills of the sample ranged from intellectually impaired to above the average-level abilities found in the general population. Furthermore, the data analyses identified subgroups on the basis of performance. Approximately 25 per cent of the sample possessed "normal" language skills, in that their scores fell within the normal range in all the measures administered. The majority of these children also showed normal levels of intelligence, although as some of these individuals were intellectually impaired, it was concluded that language subtypes were not entirely determined by intellectual abilities. The second subgroup showed impaired language abilities, in that they scored more than one standard deviation below the mean across most of the language tests. Again, this group included both children, whose intelligence lay within the normal bounds, as well as intellectually impaired range. Interestingly, whilst these children showed unimpaired articulation skills, their performance in higher-level semantic and syntactic measures was poorer than their vocabulary and nonsense word repetition skills. This pattern of linguistic performance has also been identified in children with specific language impairment (SLI) (Tomblin & Zhang, 1999), and indeed, a follow-up study confirmed that the language impairment in some children with autism and that observed in SLI overlap (Tager-Flusberg, in press). The remainder of the children showed a profile that was borderline normal, and their performance across the different tests did not consistently fit any of the subtype patterns. This research effort clearly confirmed that there is no single language phenotype in autism. Rather, two subtypes were evident: in one, children possessed normal linguistic but not pragmatic abilities, and in the other, the language profile matched that seen in individuals with SLI.

Another line of research has attempted to identify subtypes of autism on the basis of the different cognitive profiles that are seen in the disorder. In particular, a profile whereby individuals exhibit superior non-verbal intellectual abilities in relation to verbal skills, has been identified as being the most characteristic of the autistic disorder (Lincoln, Courchesne, Kilman, Elmasian, & Allen, 1988). However, this profile is not universal in autism (Siegel, Minshew, & Goldstein, 1996), and the inverse profile, whereby individuals show superior verbal skills in relation to non-verbal abilities, has been specifically associated with high-functioning autism (e.g., Manjiviona & Prior, 1999). Indeed, it has been suggested that language abilities serve an important mediating influence on the expression of symptom severity in autism (Bailey et al., 1996). In one study, Joseph, Tager-Flusberg, and Lord (2002) examined the relationship between the different cognitive profiles seen in autism, divided on the basis of discrepancies in the verbal and non-verbal intellectual abilities, and the severity of both the social and communication deficits, in children with the disorder. In this study, 47 children, aged between six and 13 years, were administered the Differential Abilities Scale (DAS) (Elliott, 1990), which yields a verbal and non-verbal intelligence score on the basis of performance in six subtests. Furthermore, the children's social and communication deficits were assessed by the Autism Diagnostic Observation Schedule (ADOS) (Lord, Risi, Lambrecht, Cook, Lenventhal, DiLavore, Pickles, & Rutter, 2000). The findings showed that over sixty per cent of the children exhibited cognitive profiles in which uneven patterns of functioning were in evidence in both the verbal and non-verbal domains. Approximately one third of the sample showed a profile in which non-verbal functioning was superior to verbal performance; another third exhibited the reverse profile, and the remaining third showed even abilities in the verbal and non-verbal domains. The findings further showed that verbal ability was inversely associated with deficits in social functioning, specifically in communication. Thus, children with proportionally higher non-verbal than verbal intellectual ability presented escalating deficits regarding social interaction. These impairments were found to be independent of the children's absolute verbal and overall intellectual abilities. As the children with discrepantly higher verbal than non-verbal ability showed no escalating social deficits, these results are in line with those reported by Bailey et al. (1996). This led Joseph and colleagues to suggest that in these children, verbal skills might have compensated for, and to some extent masked, their deficits in the social domain. Finally, although the children with even intellectual abilities showed levels of verbal intelligence that were significantly below those seen in the superior verbal intelligence group, and similar to those found in the discrepantly higher non-verbal intelligence group, these children's social-communicative functioning was indistinguishable from that of the children with superior verbal abilities. Consequently, the authors suggested that the cognitive profile in which non-verbal intellectual functioning was disproportionally higher to that seen in the verbal domain, may reflect a particularly severe underlying brain pathology (Joseph et al., 2002). Indeed, it has been hypothesised that proportionally over-developed visuo-perceptual abilities may be indicative of increased neuronal growth, decreased cortical pruning, and reduced brain connectivity, in individuals with autism (Cohen, 1994; Happé, 1999). In support of this, a follow-up investigation by Deutsch and Joseph (in press) identified a link between the cognitive profile in which non-verbal abilities are superior to verbal abilities and observations of increased head circumference in some children with autism, thereby providing appealing evidence for this subtype of autism having a specific biological basis.

As was noted in the introduction to this thesis, persistent semantic deficits have frequently been linked to the language disorder seen in autism (Simmons & Baltaxe, 1975; Minshew, Goldstein, & Siegel, 1995; Tager-Flusberg, 1989; 2001b). Although such deficits are not a universal feature of the disorder, unlike those seen in pragmatics, it is interesting to consider a study carried out by Allen and Rapin (1992). These authors analysed a group of 491 pre-school age children, of which 229 were diagnosed with an autistic spectrum disorder, and 262 with a developmental language disorder. The findings showed that whilst none of the children with autism showed normal comprehension of speech, over a third of the children with the language disorder did so. These findings suggest that semantic deficits may be even more marked in young children with autism than they are in older individuals. Some distinctive manifestations of the semantic difficulties seen in autism include a failure to utilise semantic information to encode and recall verbal information (Hermelin & O'Connor, 1967; Tager-Flusberg, 1991), a tendency to emphasise syntactic features of speech over semantics (Tager-Flusberg, 1991), and a reduced tendency to interpret words in a semantic context (Frith & Snowling, 1983; Happé, 1997). Furthermore, there is evidence to show that the neural processing of semantic information is abnormal in autism (Dunn, Vaughan Jr., Kreuzer, & Kurtzberg, 1999).

From the developmental perspective, Menyuk and Quill (1985) have suggested that semantic development in typical children occurs in two steps: firstly, children acquire the understanding of categorical meaning, followed by that of relational meaning, of lexical items. In typical development, the order in which the categorical meaning of lexical items is understood is assumed to be determined by three factors. Firstly, their communicative importance; second, their phonology; and third, the frequency with which the items or events occur in the environment. It thus follows that items referring to self and other important persons for the child (e.g., mother), and those that occur frequently in the environment, that are concrete, easily described and identified are acquired first. In the case of autism, as the diagnosis can only be given at the age of three years, little is known about the early vocal development in this population. Research with older verbal children with autism has shown that although phonology and general word acquisition are not specifically affected by the disorder (e.g., Tager-Flusberg, Calkins, Nolin, Baumberger, Anderson, & Chadwick-Dias, 1990), and may even appear precocious (e.g., Bartolucci & Pierce, 1977), the use of lexical items, is nevertheless, atypical. For example, the use of "neologisms" has been noted, which are words with a special meaning not shared by both speaker and listeners (Kanner, 1946; Volden & Lord, 1991). Secondly, mental state terms have been found to be underrepresented in the vocabularies of such children (Tager-Flusberg, 1992; Tager-Flusberg & Sullivan, 1994). It has been suggested that this derives from theory of mind deficits. Taken together, whilst overall lexical development in autism may be an area of relative strength, it has been suggested that the acquisition of words that represent mental state concepts might be selectively impaired by the disorder (Tager-Flusberg, 2001b). Furthermore, children with autism have been found to show impairments in the acquisition of communicatively important lexical items referring to self and others. For example, one common characteristic of the speech of children with autism is the use pronoun reversal. Here, the children refer to themselves as "you", and their listener as "I", and such mistakes are considered to be an important aspect of the diagnosis of autism (American Psychiatric Association, 1994; Le Couteur, Rutter, Lord, Rios, Robertson, Holdgrafer, & McLennan, 1989). It has been suggested that the pronoun reversal errors reflect deficits in the conceptualisation of self and others in autism (Tager-Flusberg, 1993; 1994).

In typical development, the intuitive understanding of categorical relations is suggested to grow in synchrony with vocabulary acquisition (Menyuk & Quill, 1985), It has also been postulated that children acquire word meanings by gradually adding up perceptual aspects (Clark & Clark, 1977). This development is proposed to take place in the following steps (see Menyuk & Quill, 1985). Firstly, the child specifies a particular object, for example, a cup. This word is then placed into a wide category (over-generalisation), before the child learns to narrow it down to only include items that contain certain specific "criterial" features (differentiation). The word's meaning is then related to other word meanings, by which superordinate classes are formed (generalisation). Finally, the child learns to use the word in such a fashion that it can have multiple meanings, for example, as a noun or verb, but also figuratively. Although it has been hypothesised that the idiosyncratic use of language by individuals with autism reflects difficulties in generalisation, research findings have been mixed. For example, two language studies found no significant differences in the ability to organise and represent object concepts within taxonomic hierarchies between children with autism and age- and verbal intelligence matched typically developing and intellectually impaired controls (e.g., spaniel-dog-animal) (Boucher, 1988; Tager-Flusberg, 1985a). Further studies examining the production and comprehension of word meanings in children with autism found that their ability to extend word meanings to a range of novel exemplars was intact (e.g., labelling a novel picture of a dachshund as a dog) (Tager-Flusberg, 1985b; 1986). However, perceptual processing studies have found evidence of reduced generalisation in autism. Indeed, as was mentioned in the introduction to this thesis, one theory of autism explains the enhanced perceptual processing, frequently noted in such individuals, as arising from their impoverished ability to generalise between stimuli (Plaisted, 2001). In this processing style, unique features of stimuli are processed with high acuity, at the expense of processing similarities between the stimuli. This tendency results in reduced generalisation and categorisation of stimuli. According to this model, this processing style is assumed to impinge upon all levels of psychological processing, including language. Support for this hypothesis was found in a perceptual learning task, where individuals with autism showed superior performance in discriminating between two novel, non-pre-exposed stimuli, as compared to their controls; by contrast, their controls showed better performance in discriminating between two pre-exposed stimuli (Plaisted, O'Riordan, & Baron-Cohen, 1998). With regard to the proposed deficits in categorisation, Plaisted and colleagues cited evidence from a prototype abstraction task (Plaisted, O'Riordan, Aitken, & Killcross, submitted; cited in Plaisted, 2001) in support. Here, participants were first trained to categorise two sets of exemplars. In typically developing individuals, subsequent categorisation of the prototype of each set is expected to be more accurate than that of other non-prototypical exemplars, even in cases where the prototypes are novel. This effect is assumed to arise because the categorisation of prototypes relies upon the estimation of the similarity between exemplars. Furthermore, as the prototype is the central tendency of the set of training exemplars, its resemblance to the training set will be greater than that of any novel but non-prototypical exemplar, leading to more accurate categorisation. The findings showed that the participants with autism showed significantly poorer category learning in initial categorisation of the prototype than their typical controls, and also a reduced prototype effect. Thus, these perceptual findings stand in sharp contrast to the studies carried out in the linguistic domain. Plaisted (2000) argues that one possible reason for this discrepancy is that the linguistic studies have not actually assessed the ability of children with autism to create categories, but rather, have examined the children's pre-existing knowledge of concepts such as animals, vegetables, or vehicles. Taken together, the discussion presented above suggests that there is no consensus on the possible mechanisms underlying the semantic processing deficits in autism. Indeed, abilities relating to either conceptualisation, categorisation, and/or generalisation might be crucial in this respect. Furthermore, it is difficult to draw any firm conclusions about, for example, categorisation abilities in autism, as inconsistent findings have been obtained in the perceptual and linguistic domains. However, it has been suggested that, in typical development, visual-perceptual abilities may influence semantic development. It is therefore interesting to examine how the atypical perceptual processing style may be linked to semantic deficits in autism.

From the perspective of an interactional model of language (see Bloom & Lahey, 1978; Tager-Flusberg, 1997; 1999, for a discussion), language acquisition is assumed to represent the integration of developments in the conceptual, linguistic, and social domains. Concerning the relationship between developments in the linguistic and social domains, Tomasello (1995) and Sabbagh (1999) have argued strongly that pragmatics play an important role in all stages of language acquisition. It has been shown, for example, that an appreciation of the communicative intentions of others guides children's hypotheses about object names (Tomasello & Barton, 1994), grammatical form-class judgements (Tomasello & Akhtar, 1995), and word meanings (Akhtar & Tomasello, 1996), via joint attention. As was mentioned in the introduction to this thesis, young children with autism show marked deficits in joint attention behaviours (Mundy, Sigman, & Kasari, 1990; 1993). It is of relevance here is to consider a recent study by Charman (2003), which led him to propose that joint attention is a pivotal skill in autism. This longitudinal study assessed language abilities together with symptom severity in young children with either autism or a related pervasive developmental disorder. The findings showed that in children with autism, joint attention ability at as early as 20 months was positively associated with language skills and less severe social and communication deficits, at 42 months. Consistent findings have also been reported in other similar, longitudinal studies involving older children with autism (Sigman & Ruskin, 1999; Stone & Yonder, 2001). Thus, it can be expected that, from very early on in development, language acquisition follows an atypical developmental trajectory in autism from the social perspective. Bridging the developments in the semantic and social domains, Frith and Happé (1994) have suggested that atypical semantic development in autism might be related to difficulties in appreciating the importance of communicative intentions of others. As was discussed in detail in chapter seven, according to Relevance theory (Sperber & Wilson, 1995), the understanding of the meaning of utterances is intrinsically linked to the understanding of intention, relying upon meta-representational ability. Indeed, findings from experiment six highlighted marked deficits in the understanding of communicative intention in autism. In the light of this, it is hypothesised that children with autism with high levels of semantic competence will show greater pragmatic-prosodic understanding than those with lower semantic processing ability.

Experiments two, three, four, and five, presented earlier in this thesis, found that children with autism showed enhanced perceptual abilities in processing pitch and rhythm in speech stimuli compared to their age- and intelligence matched controls. However, when the children's understanding of the linguistic function of such prosodic cues was assessed, marked deficits were in evidence. These findings appear to suggest that auditory perceptual processing is poorly linked with linguistic abilities in autism. However, although findings from experiments two and five found evidence of significantly compromised semantic processing in autism, over a third of the children exhibited a processing style that was associated with high-level ability in both the perceptual and semantic domains. As children have been proposed to acquire word meanings by the gradual adding up of perceptual features (Clark & Clark, 1977), which is related to developments in generalisation and categorisation (Menyuk & Quill, 1985), it is interesting to wonder how the atypical perceptual processing of speech in autism is related to semantic ability. The reduced generalisation model (Plaisted, 2001) assumes that semantic deficits result from a processing style whereby unique features of stimuli are presented with high acuity, resulting in deficits in generalisation and categorisation. Although, in this thesis, no studies have directly examined generalisation and categorisation abilities in autism, it is interesting to note that findings from experiments two, four, and five found a domain-general ability in children with autism to process pitch and rhythm information across different stimulus classes, whilst no such ability was evident in the controls. Furthermore, as the subgroup findings from experiments two and five showed that enhanced perceptual abilities co-existed with high semantic ability in some children with autism, these results clearly challenge the predictions of the model proposed by Plaisted (2001). Thus, it is interesting to further elucidate the relationship between perceptual processing and higher-level speech processing abilities in autism.

METHOD

It was possible to sub-divide the children tested in experiments two, three, four, five, and six, on the basis of their semantic processing ability. Experiments two and five included a semantic processing measure, whereby the children's ability to answer simple control questions relating to the semantic content of short sentences was assessed. As this task required some expressive language ability, only children who had phrasal level expressive speech were included. Out of this group of children, three children with autism, who consistently scored above 85 per cent correct in the semantic processing measures, were selected. These children were labelled the "highest semantic processors", and their age- and psychometric characteristics are shown in Table 8.1. In a similar fashion, three children, who consistently showed floor level semantic processing ability, specifically obtaining scores that were less than 15 per cent correct in the semantic processing measures, were identified. These children were labelled the "lowest semantic processors", and their age- and psychometric characteristics (BPVS and Raven's standardised scores) are displayed in Table 8.2. It is noteworthy that the semantic processing scores of complete sample of children with autism ranged from zero to 100 per cent correct in both measures. However, as some of the low scoring children were virtually non-verbal, they were excluded from this analysis.

RESULTS

Table 8.1 shows both the age- and psychometric characteristics (standardised BPVS and Raven's scores), as well as performance scores in percentages, for all of the experimental and PEPS-C tasks presented in this thesis, as attained by the three children with autism who showed ceiling level performance (85 % correct) in the semantic processing measures used in experiments two and five. The column on the far right displays the means and ranges of scores (in percentages) for the complete autism sample.

Table 8.1 Age- and psychometric data, alongside performance scores (in %) obtained in the experimental and PEPS-C tasks, for the three children labelled the "highest semantic processors"

	Highest semantic processors			Complete autism sample
	Child HA (male)	Child HB (male)	Child HC (male)	
Age; (BPVS); Raven's	**11yr;10m;(98);119**	**17yr;0;(70);92**	**15yr;11;(84);94**	**12yr;0m;(77);89**
Pitch contour; Exp.2				**Mean (Range)**
%correct speech	75	56.3	93.8	56.8 (25-93.8)
%correct music	93.8	75	100	57.8 (18.8-100)
Default study; Exp.3				
%perceptual choices	62.5	20.8	66.7	35.3 (0-95.8)
%semantic choices	37.5	79.2	33.3	64.7 (4-100)
%correct perceptual choices	80	80	75	73.6 (0-100)
%correct semantic choices	89	89	75	72 (0-100)
Equivalent pitches; Exp.4				
%correct speech-speech	58.3	75	missing data	62.5 (37.5-83.3)
%correct music-music	70.8	91.7	missing data	64 (50-95.8)
%correct speech-music	58.3	62.5	missing data	60.5 (41.6-91.7)
Rhythm patterns; Exp.5				
%correct intact speech	93.8	93.8	62.5	57.2 (25-100)
%correct pseudo-speech	75	75	68.8	57.2 (12.5-100)
PEPS-C input tasks				
%correct total	93.8	89.6	97.9	70.7 (49-97.9)
%correct affect	68.8	62.5	100	72.3 (31.3-100)
%correct chunking	100	100	87.5	68.4 (37.5-100)
%correct focus	93.8	87.5	100	66.9 (50-100)
%correct intonation	100	93.8	100	79.2 (37.5-100)
%correct prosody	100	93.8	100	68.4 (31.3-100)
%correct turn-end type	100	100	100	69.1 (37.5-100)
PEPS-C output tasks				
%correct total	96.4	missing data	91.7	76.1 (50.5-96.9)
%correct affect	87.5	missing data	100	85.4 (31.3-100)
%correct chunking	100	missing data	68.8	58.3 (31.3-100)
%correct focus	100	missing data	81.3	75.5 (43.8-100)
%correct intonation	100	missing data	100	87.5 (37.5-100)
%correct prosody	90.6	missing data	100	83.6 (28.1-100)
%correct turn-end type	100	missing data	100	66.2 (31.3-100)
Statement-question, Exp.6				
%correct declaratives	91.6	100	100	71.7 (16.7-100)
%correct questions	16.7	83.3	50	44.6 (8-100)
PEPS-C turn-end type input				
%correct declaratives	100	100	100	72.6 (0-100)
%correct questions	100	100	100	65.5 (0-100)

Table 8.2 shows both age- and psychometric characteristics (standardised BPVS and Raven's scores), as well as performance scores in percentages, for all of the experimental and PEPS-C tasks presented in this thesis, for the three children with autism who showed floor level performance (15 % correct) in the semantic processing measures used in experiments two and five. The column on the far right displays the means and ranges of scores (in percentages) attained by the complete autism sample.

Table 8.2 Age- and psychometric data, alongside performance scores (in %) obtained in the experimental and PEPS-C tasks, for the three children labelled the "lowest semantic processors"

	Lowest semantic processors			Complete autism sample
	Child LA (male)	**Child LB (male)**	**Child LC (male)**	
Age; (BPVS); Raven's	**9yr;9m;(76);105**	**8yr;1m;(86);82**	**12yr;10m;(55);80**	**12yr;0m;(77);89**
Pitch contour; Exp.2				**Mean (Range)**
%correct speech	68.8	62.5	50	56.8 (25-93.8)
%correct music	56.3	68.8	31.3	57.8 (18.8-100)
Default study; Exp.3				
%perceptual choices	91.7	45.8	16.7	35.3 (0-95.8)
%semantic choices	8.3	54.2	83.3	64.7 (4-100)
%correct perceptual choices	36	82	50	73.6 (0-100)
%correct semantic choices	50	69	55	72 (0-100)
Equivalent pitches; Exp.4				
%correct speech-speech	54.2	79.2	37.5	62.5 (37.5-83.3)
%correct music-music	62.5	50	50	64 (50-95.8)
%correct speech-music	62.5	70.8	75	60.5 (41.6-91.7)
Rhythm patterns; Exp.5				
%correct intact speech	56.3	missing data	56.3	57.2 (25-100)
%correct pseudo-speech	81.3	missing data	50	57.2 (12.5-100)
PEPS-C input tasks				
%correct total	63.5	52.1	55.2	70.7 (49-97.9)
%correct affect	50	37.5	62.5	72.3 (31.3-100)
%correct chunking	37.5	62.5	75	68.4 (37.5-100)
%correct focus	62.5	50	68.8	66.9 (50-100)
%correct intonation	93.8	81.3	37.5	79.2 (37.5-100)
%correct prosody	87.5	31.3	31.3	68.4 (31.3-100)
%correct turn-end type	50	50	56.3	69.1 (37.5-100)
PEPS-C output tasks				
%correct total	missing data	69.8	missing data	76.1 (50.5-96.9)
%correct affect	missing data	62.5	missing data	85.4 (31.3-100)
%correct chunking	missing data	31.3	missing data	58.3 (31.3-100)
%correct focus	missing data	81.3	missing data	75.5 (43.8-100)
%correct intonation	missing data	96.9	missing data	87.5 (37.5-100)
%correct prosody	missing data	96.9	missing data	83.6 (28.1-100)
%correct turn-end type	missing data	50	missing data	66.2 (31.3-100)
Statement-question,Exp.6				
%correct declaratives	50	16.7	14.7	71.7 (16.7-100)
%correct questions	58.3	50	33.3	44.6 (8-100)
PEPS-C turn-end type input				
%correct declaratives	62.5	100	100	72.6 (0-100)
%correct questions	37.5	0	12.5	65.5 (0-100)

DISCUSSION

Four questions will be addressed here. The first concerns the age- and psychometric profiles of the children with autism who showed high- and low semantic processing ability. The second question addresses the relationship between the semantic competence and perceptual processing abilities in speech and musical stimuli. Thirdly, semantic processing ability will be examined in relation to any perceptual/semantic speech processing biases. Finally, the children's semantic competence will be examined in relation to pragmatic-prosodic higher-level linguistic abilities. With regard to the latter point, it was hypothesised that children with high semantic ability would show better pragmatic understanding than those with low semantic ability.

Relationship between age- and psychometric characteristics and semantic competence

Table 8.3 shows both the mean age- and psychometric data (standardised BPVS and Raven's scores) for the highest and lowest semantic processors alongside those for the complete autism sample.

Table 8.3 Mean age- and psychometric data for both the highest and lowest semantic processors, presented alongside those for the complete autism sample

	Highest semantic processors	**Lowest semantic processors**	**Complete autism sample**
	Mean (N=3)	**Mean (N=3)**	**Mean (N=25)**
Chronological age	14yr;11m	10yr;3m	12yr;0m
VIQ (BPVS)	84	72	77
NVIQ (RPM)	102	89	89

Table 8.3 shows that the three children labelled the "highest semantic processors" were substantially older than the three children who showed low ability to process speech for

meaning. However, no relationship between age and semantic processing ability was found in any of the experiments that included a semantic processing measure (i.e., experiments two, three, and five). Therefore, for the children with autism, semantic processing ability was not found to be significantly associated with age. These findings are consistent with those of Kjelgaard and Tager-Flusberg (2001).

Table 8.3 further shows that the difference in the mean standardised verbal intelligence scores between the children in the high- and low semantic processing groups was less than one standard deviation. In experiments two, three, and five, verbal intelligence was consistently associated with semantic processing ability in the larger sample of children with autism. It is noteworthy, however, that verbal intelligence was assessed using the BPVS, which is a purely receptive measure of vocabulary, and involves single-word-to-picture mapping. This measure is thus limited in its qualitative scope, and might not be representative of the children's higher-level language abilities. As can be seen from Tables 8.1 and 8.2, all the children, regardless of semantic ability, had verbal intelligence scores broadly within the intellectually unimpaired range (70 or above), except for the child LC in the low semantic processing group. However, higher-level language processing abilities in autism have been found to be incompletely determined by the level of children's verbal intelligence as measured by the BPVS or its equivalents (e.g., Kjelgaard & Tager-Flusberg, 2001). It is likely that this finding holds the current subgroups of children with autism, as their mean verbal intelligence scores did not significantly differ.

Table 8.3 shows that the difference in the mean standardised non-verbal intelligence scores between the high- and low semantic processors was, again, less than one standard deviation. Interestingly, in experiment two, where the data from high- and low-functioning children with autism were analysed separately, semantic processing ability in the high-functioning children was associated with non-verbal intelligence, and not with verbal ability, as was the case for the complete sample and also for the low-functioning children. A similar association was reported in a semantic memory study by Toichi and Kamio (2001), which led the authors to suggest that semantic processing might be qualitatively different in autism to that seen in typical development. Whilst the mean non-verbal intelligence score for the high semantic processors was higher than that of the sample mean, the mean non-verbal intelligence score for the low semantic processors was equal to that of the complete autism sample. Thus, it may be, as indeed was suggested by Toichi and Kamio (2001), that non-verbal intelligence is important to semantic processing ability in autism. This suggests that rather than using explicitly verbal intellectual abilities, individuals with autism might rely upon general cognitive abilities when processing speech for meaning. Similar suggestions have been made in connection with the pragmatic, theory of mind related performance of individuals with autism (e.g., Bowler, 1992; Happé, 1995; Happé, Ehlers, Fletcher, Frith, Johansson, Gillberg, Dolan, Frackowiak, & Frith, 1996). Five out of the six children exhibited an intelligence profile in which non-verbal intelligence exceeded verbal ability, and in four cases, this discrepancy was greater than 20 IQ points; however, the children in question represented extreme subgroups. Thus, this profile was not specific to the children with poor semantic processing ability. The remaining child LB in the low semantic processing group exhibited even verbal and non-verbal abilities. However, as the BPVS and RPM have been standardised with different samples of children, the standardised scores cannot be considered as strictly "equal" across the two tests. All of the children's non-verbal intelligence scores fell broadly within the normal range.

In the context of the findings reported by Joseph and colleagues (2002), the current pattern of cognitive profiles of the children may seem surprising. Firstly, as all the children in the high semantic processing group, and two of the three children in the low semantic processing group, exhibited a VIQ<NVIQ profile, this cognitive profile did not explain the children's semantic processing ability. Possible explanations for this discrepancy concern the small sample size of the current subgroups. Another possibility is that the high semantic processors in the present study represented a subgroup within the subgroup of children who show a VIQ<NVIQ profile. Furthermore, it is surprising that the child LB, with a non-discrepant cognitive profile, showed low semantic processing ability. In the study by Joseph et al. (2002), children with such a profile exhibited comparable social-communicative functioning to those with discrepantly high verbal abilities, and these children outperformed those with a VIQ<NVIQ cognitive profile on the social-communicative measures. In their study, Joseph and colleagues (2002) further suggested that verbal abilities may have acted as a mediator in compensating for children's deficits in the social-communication domain; however, as the difference in the standardised verbal intelligence scores between the two current subgroups of children was small, verbal abilities as measured by the BPVS are unlikely to explain the differences in the children's semantic processing ability.

Relationship between pitch processing ability and semantic competence

This section will be concerned with relating the children's semantic processing ability to their performance in the experiments that have assessed the ability to process pitch; namely experiments two and four.

Pitch contour processing (experiment two)

Experiment two tested the children's ability to extract four different pitch contours from analogous speech and musical stimuli. Neither the level of verbal nor non-verbal intelligence contributed towards the children's performance in the larger sample. Table 8.4 shows the mean performance scores in percentages for both the children with high- and low semantic processing ability, alongside those for the complete autism sample.

Table 8.4 Mean performance scores (in %) in experiment two for both the high- and low semantic ability subgroups, alongside those for the complete autism sample

	Speech condition	**Music condition**
	Mean % correct	**Mean % correct**
Highest semantic processors (N=3)	75	89.6
Lowest semantic processors (N=3)	60.4	52.1
Complete autism sample (N=25)	56.8	57.8

Table 8.4 shows that the high semantic processors were better at extracting the pitch contours from musical as compared to speech stimuli. By contrast, the low semantic processors showed better performance in the speech condition compared to the music condition. One possible explanation for this might be that, as the low semantic processors are expected to show a weakened semantic processing focus, this might enable them to develop finely-tuned discrimination abilities with regard to verbal stimuli, as speech is being heard more often than music. It is evident, however, that the high semantic processors exhibited superior overall pitch processing ability compared to children with low semantic competence. The finding that the low semantic processors showed superior performance in the speech condition may suggest that the high semantic processors were more "captured" by the linguistic content of the speech stimuli, and thus showed superior performance with the musical stimuli. In the light of

the findings for the complete autism sample, the high semantic processors showed substantially higher levels of performance especially in the music condition, whilst the low semantic processors performed below the sample mean in the music condition. It is interesting to note that, whilst no between-condition effects were observed for the complete autism sample, the subgroups of children showed discrepant and opposite patterns of performance across the conditions. This may be explained by these children's semantic processing bias, a reduction in such focus, or else by higher-level language abilities. It is again possible that these findings arose as a consequence of the children in question representing extreme subgroups.

Pitch sequence discrimination (experiment four)

Experiment four tested the children's ability to discriminate between pitch sequences in same-different pairs of speech-speech, music-music, and speech-music stimuli. Neither non-verbal nor verbal intelligence correlated with the performance of the children with autism in any condition for the larger sample. Table 8.5 shows the mean performance scores in percentages for both the children with high- and low semantic processing ability, alongside those for the complete autism sample.

Table 8.5 Mean performance scores (in %) in experiment four for both the high- and low semantic ability subgroups, alongside those for the complete autism sample

	Speech-speech condition	Music-music condition	Speech-music condition
	Mean % correct	**Mean % correct**	**Mean % correct**
Highest semantic processors (N=3)	66.7	81.25	60.4
Lowest semantic processors (N=3)	57	54.2	69.4
Complete autism sample (N=23)	62.5	64	60.5

An inspection of the performance of the high semantic processors shows that, again, these children exhibited highly enhanced performance in the condition where both stimulus pairs were music, when compared to the low semantic processors and to the complete autism sample. Their performance was also substantially higher in this condition than it was in the conditions incorporating speech stimuli. Furthermore, this subgroup performed marginally better with the speech-speech stimuli compared with the cross-domain speech-music stimuli. Interestingly, this subgroup performance pattern very closely mirrors that obtained for the control children, albeit at a higher level, thus being consistent with the findings from the autism group as a whole. Thus, it might be suggested that the attentional mechanisms in speech processing of the high semantic processors were more similar to those found in typical development, where semantic speech processing bias is extremely robust, than was the case for the low semantic processors.

In contrast, the low semantic processors exhibited the opposite pattern of performance: these children showed by far their best performance with the cross-domain stimuli as compared with the speech-speech and music-music pairs. It is evident yet again that these children showed the poorest levels of performance in the music-music condition. Although the overall levels of performance were lower in the low semantic processing group in comparison to the high semantic processors, it is striking that their performance was substantially better in the speech-music condition than that of the high semantic processors. It could be argued that the cross-domain stimuli represented the most difficult condition, as the two parts of the stimuli tap into different neural processing mechanisms. Thus, these results suggest that the low semantic processors treated the speech and musical stimuli in much more similar fashion than did the high semantic processors.

Taken together, the findings from experiments two and four suggest that pitch processing abilities in the two subgroups were qualitatively different depending upon the children's level of semantic processing ability. High semantic processing ability was associated with enhanced perceptual processing skills, especially in music, and also with superior overall auditory-perceptual discrimination abilities. In contrast, the low semantic processors showed relative strengths when they were required to judge the pitch sequences across different stimulus domains (speech and music), or in the speech domain only. It could be argued that these different patterns of performance may reflect different degrees of neural specialisation in the speech domain between the children (see chapter four for a discussion).

In the light of the reduced generalisation theory (Plaisted, 2001), suggesting that semantic deficits may arise as a result of impairments in generalisation and categorisation in autism, the current finding that the low semantic processors showed an enhanced ability to discriminate pitch information across different domains suggests a better generalisation ability in these children, as compared with the high semantic processors. Thus, the current findings are at odds with studies carried out in the visual domain (e.g., Plaisted et al., 1998). The finding that the high semantic processors exhibited an overall superior auditory-perceptual ability suggests that these children showed particularly acute perceptual processing. As, according to the predictions of the reduced generalisation model, this processing style would be associated with particularly reduced generalisation and categorisation ability, the current findings are consistent with this prediction to the extent that, unlike the low semantic processors, these children failed to show a domain-general pitch processing ability. However, as semantic ability would be assumed to reflect normal generalisation and categorisation (Menyuk & Quill, 1985), the finding that the high semantic processors also exhibited enhanced perceptual processing cannot be explained within this framework.

The current findings are striking when considered in the light of the finding that both groups of children exhibited a cognitive profile in which relative strengths were observed in the non-verbal intelligence domain. Such strengths have traditionally been considered to reflect "spared" perceptual abilities, particularly those tapped by the visual-perceptual tests, such as the Wechsler block design, which require negligible global, social, or verbal reasoning (Lincoln, Courchesne, Kilman, Elmasian, & Allen, 1988). In the light of the other influential non-social theories of autism, the weak central coherence (WCC) hypothesis would posit that the enhanced perceptual processing abilities are attributable to a local processing bias resulting from a top-down deficit in central coherence (Frith & Happé, 1994; Happé, 1999). Other alternative theories consider such abilities as resulting from the abnormal development of low-level perceptual processes (Mottron & Burack, 2001; Plaisted, 2001). At the same time, weak central coherence is hypothesised to directly interfere with the processing of global level information, for example, semantics. Alternatively, in the other perceptual theories, such as the theory of enhanced perceptual functioning (EPF) (Mottron & Burack, 2001), there is assumed to be an under-development of the higher-level cognitive processes that underpin global processes. Much like the reduced generalisation model (Plaisted, 2001), the WCC and EPF theories assume that this featurally-biased processing style impinges upon all levels of psychological functioning in autism. Thus, the current findings present some challenges for these models, as they cannot explain why the high semantic processors with ostensibly intact global processing ability should exhibit co-existing superior perceptual skills, as compared to those with low semantic processing ability. Indeed, the opposite would be predicted. However, the current findings are consistent with studies that have failed to establish a global processing deficit in the auditory domain in autism (e.g., Heaton, in press; Mottron et al., 2000). In the introduction to this chapter, it was suggested that the theories outlined above may provide excellent frameworks for explaining subgroup performance in autism. It appears that the performance of the current subgroups, formed on the basis of high and low global, semantic ability, failed to conform to the predictions of any of these models.

Finally, the finding that the high semantic processors showed highly enhanced pitch processing skills raises questions about the relationship between auditory-perceptual processing abilities and language acquisition in autism. Although it should be emphasised that only three children were studied, it might be speculated that in some children with autism, superior auditory processing skills can enable them to acquire language. As the most important prosodic effects are produced by pitch variations (Lieberman, 1960), it may be that the outstanding pitch discrimination skills of some children enable them to segment speech on the basis of prosody, and subsequently learn to attach meaning to such segments. It is of relevance to note here that in addition to visual-perceptual skills (Clark & Clark, 1977), auditory-perceptual abilities have been suggested to facilitate language acquisition. In specific language impairment (SLI), one theoretical account speculates that the fundamental deficit is perceptual rather than linguistic in nature (Tallal, 2000). It has been shown that, whilst in individuals with frequency discrimination difficulties, language abilities remain affected throughout the life-time, auditory processing skills have been found to normalise in some individuals during the course of development (Bishop & McArthur, in press). In a similar vein, it was noted in the introduction to this thesis that individuals with autism have been shown to exhibit deficits at the early stages of auditory processing (Plaisted, Saksida, Alcántara, & Weisblatt, 2003). It is thus possible that the severity of such impairment varies in autism, as indeed is the case in SLI. It would then follow that the low semantic processors may have presented more marked auditory processing deficits than the high semantic processors, resulting in poorer linguistic and auditory discrimination abilities in general. However, further studies are needed to address these issues.

Relationship between rhythmic processing ability and semantic competence

Experiment five tested the children's ability to extract four different syllabic rhythm patterns from short intact speech and pseudo-speech samples. Table 8.6 shows the mean performance scores in percentages for both the children with high- and low semantic processing ability, alongside those for the complete autism sample.

Table 8.6 Mean performance scores (in %) in experiment five for both the high- and low semantic ability subgroups, alongside those for the complete autism sample

	Speech condition	**Pseudo-speech condition**
	Mean % correct	**Mean % correct**
Highest semantic processors (N=3)	83.3	72.9
Lowest semantic processors (N=3)	56.3	65.6
Complete autism sample (N=21)	57.2	57.2

As can be seen from Table 8.6, the high semantic processors were better able to process rhythmic patterns in intact speech as compared to pseudo-speech stimuli. Interestingly, this pattern is the reverse to that found for the control children, suggesting that semantic processing ability resulted in different processing patterns in children with autism as compared to those with typical development. In contrast, the low semantic processors exhibited the same pattern of performance as the controls, showing higher levels of performance with the pseudo-speech as compared with the intact speech stimuli. Overall, the high semantic processors showed higher levels of perceptual ability than the children with low semantic competence, conforming to the earlier findings from the pitch processing studies. Taken together, these results suggest that semantic ability is indeed associated with enhanced perceptual abilities in autism.

Interestingly, whilst no between-condition differences were in evidence for the complete autism sample, the subgroups exhibited discrepant and reverse performance patterns. More specifically, the findings that the high semantic processors showed higher levels of performance with the intact speech as compared to the pseudo-speech stimuli, and that the low semantic processors exhibited the reverse pattern, might appear surprising in the light of the results from the pitch processing studies discussed above. Here, the high semantic processors showed substantially higher levels of performance in the musical domain, whilst the low semantic processors showed relative strengths with speech stimuli. One explanation for the discrepant result from the current study concerns the observation that, although the task was intended to be perceptual, some of the children with high linguistic ability were noted to tackle the task by applying their knowledge of the syllabic structures of words. As the low semantic processors can be expected to have possessed poorer linguistic knowledge, it may then be less surprising that they found the pseudo-speech condition easier.

Relationship between perceptual/semantic speech processing bias and semantic competence

Experiment three assessed the tendency of children with autism to respond either to perceptual (pitch) or to semantic aspects in speech, in an attempt to identify speech processing biases in autism. Furthermore, the processing accuracy of the children's choices was analysed. Table 8.7 shows the mean proportion of perceptual and semantic choices in percentages, and the mean accuracy of such judgements, for both the children with high- and low semantic processing ability, alongside the same data for the complete autism sample.

Table 8.7 Mean proportion of choices (%) and their mean accuracy (%), in experiment three, for both the high- and low semantic ability subgroups, alongside the same data for the complete autism sample

	Perceptual choices	**Semantic choices**	**Perceptual accuracy**	**Semantic accuracy**
	Mean % proportion	**Mean % proportion**	**Mean % correct**	**Mean % correct**
Highest semantic processors (N=3)	50	50	78.3	84.3
Lowest semantic processors (N=3)	51	49	56	58
Complete autism sample (N=28)	35.3	64.7	73.6	72

An inspection of the proportion of perceptual and semantic choices made by both the high and low semantic processors shows that these children failed to exhibit a bias towards either type of processing: half of the judgements made were perceptual, and the half were semantic. Thus, both groups of children exhibited a reduced speech processing bias, which could not be explained by semantic processing ability. Data for the complete autism sample indicated that these children showed a moderate semantic bias. Thus, it is surprising that the semantic speech processing bias was even weaker in the subgroup samples as compared to the complete autism sample. The findings for the high semantic processing group are surprising, as due to their semantic ability, they may have been expected to show a strong semantic speech processing bias. When contrasted with the data from the typical control children, who showed an extremely robust semantic bias, it becomes apparent that the attentional processes in children with autism with good semantic ability were substantially different to those seen in typical development. Indeed, the high semantic processors showed strikingly enhanced perceptual processing skills relative to other children with autism, and to the typical controls.

One possible explanation for the lack of qualitative difference in the default mechanism between the high and low semantic processors concerns the fact that, as was discussed in chapter three, children with autism are specifically trained to focus upon the semantic level of speech in their specialist schools. This may result in some children learning to "suppress" any tendency, should one exist, to attend towards the perceptual aspects of speech stimuli. There is anecdotal evidence supporting this suggestion (see chapter three). Tables 8.1 and 8.2 show that, whilst none of the high semantic processors made more than 67 per cent perceptual choices, the child LA in the low semantic processing group exhibited an extremely strong perceptual bias (92% of responses). So, it might be that, in children with poor semantic processing ability, the training described above is not as successful as is the case with children who are more competent semantically. A further possibility is, as was mentioned previously, that high non-verbal intellectual ability is associated with semantic competence in autism. However, it is striking that the child LC, who exhibited the strongest semantic bias (83.3% of responses), showed floor level performance in all semantic processing tasks.

With regard to the accuracy of the children's responses, Table 8.7 shows that the high semantic processors exhibited slightly more accurate semantic than perceptual processing. The low semantic processors showed considerably lower levels of accuracy overall, and the accuracy between their perceptual and semantic responses was equal. In the light of the findings from the complete autism sample, the low semantic processors showed strikingly poor levels of performance with respect to the group mean, whilst the high semantic processors outperformed the complete autism sample. This data further strengthens the earlier conclusions that higher-level linguistic competence is associated with enhanced perceptual processing skills in autism.

Relationship between receptive and expressive prosodic processing ability and semantic competence

The PEPS-C test battery assessed the children's receptive and expressive prosodic abilities both at the form and function levels. Table 8.8 shows the mean performance scores in percentages across the six receptive and expressive subtests of the PEPS-C test battery, together with the mean total input and output scores, for both the children with high- and low semantic processing ability, alongside those for the complete autism sample. The form subtests are shown in italics.

Table 8.8 Mean performance scores (in %) in the PEPS-C test battery for both the high- and low semantic processors, alongside those for the complete autism sample

	Highest semantic processors (N=3)	**Lowest semantic processors(N=3)**	**Complete autism sample (N=21)**
	Mean % correct	**Mean % correct**	**Mean % correct**
Total input score	93.8	56.9	70.7
Affect input	77.1	50	72.3
Chunking input	95.8	58.3	68.4
Focus input	93.8	60.4	66.9
Intonation input	*97.9*	*70.8*	*79.2*
Prosody input	*97.9*	*50*	*68.4*
Turn-end type input	100	52.1	69.1
Total output score	94	69.8	76.1
Affect output	93.8	62.5	85.4
Chunking output	84.4	31.3	58.3
Focus output	90.6	81.3	75.5
Intonation output	*100*	*96.9*	*87.5*
Prosody output	*95.3*	*96.9*	*83.6*
Turn-end type output	100	50	66.2

An inspection of the data from the high semantic processors across the 12 subtests shows that these children showed ceiling level performance throughout the test. Particular areas of strength for these children appeared to be the form subtests (intonation and prosody), assessing the ability to perceive and imitate differences in intonation and prosodic patterns. It is noteworthy that abilities at the form level are considered to be a prerequisite for the corresponding abilities at the function level (Peppé, McCann, & Gibbon, 2003); this indeed seemed to hold true for this group of children, as well as for the controls. One striking finding was that all children in this subgroup exhibited the maximum level of performance in the receptive and expressive parts of the turn-end type subtest, measuring the ability to discriminate between declaring and questioning intonation. As the language profiles of the children labelled as high semantic processors suggest that these children showed unimpaired vocabulary, comprehension and prosody, it might be suggested that these children conformed to the "normal" language subgroup identified by Kjelgaard and Tager-Flusberg (2001). Furthermore, as these children also showed highly superior perceptual processing abilities, this reinforces the conclusions that enhanced perceptual processing skills in the auditory domain might be related to speech processing abilities in autism. However, it is of relevance to note that the ceiling level performance of the children with high semantic processing ability in the pragmatic processing tasks might have reflected their use of verbal, and general problem-solving skills to compensate for their deficits in the social-pragmatic domain (Bailey et al., 1996; Happé, 1995), to "hack" out solutions to prosody tasks.

In contrast, the children with low semantic processing ability showed strikingly poor levels of performance in the PEPS-C test battery, relative to the high semantic processors, and the complete autism sample. This finding lends strong support to the hypothesis that pragmatic ability and semantic competence are related functions (Frith & Happé, 1994). Only one child in the low semantic processing subgroup was able to complete the expressive subtests. Although it is difficult to speculate on the basis of a single set of scores, this data suggests that in the low semantic processing group, expressive abilities may have been relatively more advanced than receptive understanding. It may be that this finding reflects developmental differences between the high- and low semantic processors, given that the high semantic processors were older. Receptively, areas of relative strength for these children appeared to be the focus and intonation subtests. It is noteworthy here that whereas the child LA showed high levels of performance in both of the form subtests (intonation and prosody), shown in Table 8.2, the child LC showed his poorest performance in these measures. In this context, it is important to note that the child LC found the stimuli unpleasant, and thus the performance score may not reflect his true abilities. Such auditory processing abnormalities might further contribute to these children's semantic processing difficulties. This suggestion is particularly compelling in the light of the finding showing that, by contrast, none of the children with high semantic processing ability showed atypical reactions to the stimuli. However, due to the small subgroup sample size, no further conclusions can be made about this. It is interesting to consider here the finding of Plaisted and colleagues (2003), showing that individuals with autism had auditory filters that were broader than normal. As has been mentioned previously, one implication of such an abnormality is that such individuals perceive speech as more monotonic than do those with typical development. This is because in the presence of such impairment, greater discrepancies between fundamental frequencies in a signal are needed in order to hear them. Thus, as was mentioned previously, it may be that the low semantic processors were relatively more impaired in this respect than the high semantic processors, resulting in difficulties with receptive and expressive prosody. However, in the expressive domain, the child LB showed high levels of imitation ability, as measured by the intonation and prosody subtests, seemingly to contradict this hypothesis. Overall, no distinct qualitative differences in prosodic processing were in evidence between the high- and low semantic processors. The language profiles of the children with low semantic processing ability suggested that, in addition to showing impaired comprehension and vocabulary (child LC), their prosodic (and pragmatic) abilities were further affected. However, as no formal language assessment was made, it can only be speculated that these children might conform to the impaired language subtype identified by Kjelgaard and Tager-Flusberg (2001).

The current findings are informative as regarding the differences in overall speech processing ability between the children in the two subgroups. Whereas the high semantic processors exhibited ceiling level performance in the PEPS-C test battery, the performance of the low semantic processors was very poor. These findings are striking when considered in the light of the small difference in the mean standardised verbal intelligence scores between the two subgroups. As prosodic processing is a higher-level process than that involving semantics, the finding that verbal intelligence appeared to be weakly associated with both types of processing highlights some of the limitations of this test. On the other hand, it is hardly surprising that receptive vocabulary knowledge was disassociated from higher-level linguistic processing.

Relationship between pragmatic ability and semantic competence

This section will address the relationship between semantic processing competence and the ability to understand communicative intentions in speech. Table 8.9 shows the mean performance scores in percentages in both experiment six and the analogous turn-end type input subtest of the PEPS-C, for both the children with high- and low semantic processing ability, alongside those for the complete autism sample. Scores indicating a declarative bias are shown in bold.

Table 8.9 Mean performance scores (in %) in experiment six and the turn-end type input subtest for both the high- and low semantic processors, alongside those for the complete autism sample

	Highest semantic processors (N=3)	Lowest semantic processors (N=3)	Complete autism sample (N=20/21)
	Mean % correct	Mean % correct	Mean % correct
Experiment 6			
Declaratives	**97.5**	27.1	**71.7**
Questions	50	47.2	44.6
PEPS-C turn-end type input			
Declaratives	100	**87.5**	72.6
Questions	100	25	65.5

As was mentioned under the previous subheading, the high semantic processors showed the maximum level of performance in the turn-end type subtest of the PEPS-C battery, which assessed the ability to discriminate between declaring versus questioning intonation at the single-word level. Experiment six tested the same ability at the sentence-level, and was therefore a more ecologically valid investigation. An inspection of the high semantic processors' performance in experiment six shows that, whilst these children correctly identified almost all of the declarative utterances, their understanding of the questioning intonation was very much poorer. Similarly to findings from experiment six, this result suggests that whilst the PEPS-C test battery failed to elicit pragmatic deficits in these children, the more naturalistic stimuli used in experiment six revealed marked deficits in these children's ability to understand communicative intention in prosodically cued questions. This resulted in a tendency for these children to treat utterances as declarative, suggesting that they classified the stimuli on the basis of the informative intention only. This would indeed be expected on the basis of their high semantic processing ability. This bias is shown in bold in Table 8.9. In contrast, the data from the low semantic processors showed that these children exhibited a clear declarative bias with the stimuli involving one-word utterances (turn-end type). This is shown in bold in Table 8.9. In addition, these children showed low levels of performance with both declarative and question utterances in experiment six. The finding that these children showed a moderate question bias is likely to reflect their poor understanding of the task, as semantic processing ability was required in order to be able to derive the informative intention of the utterances. Taken together, it is interesting to note that, whilst the high semantic processors showed a strong declarative bias at the sentence-level, the low semantic processors showed the same bias at the single-word level. In other words, whilst the pragmatic ability of the high semantic processors was sufficient for understanding the communicative intention behind questioning intonation at the single-word level, it was insufficient for appreciating such intention at the sentence-level. By contrast, the pragmatic ability of the low semantic processors was sufficient for understanding *informative* intention at the single-word level, as was demonstrated by their strong declarative bias; however, these children were unable to appreciate either informative or communicative intention at the sentence-level. Indeed, by virtue of their low semantic processing ability, it would be expected that they were unable to derive the meaning of the sentence-level utterances. Therefore, these findings lend support to the hypothesis of Frith and Happé (1994), suggesting that semantic deficits in autism might be related to such children's ability to appreciate the communicative intentions of others.

In the light of the finding by Joseph and colleagues (2002), showing that a VIQ<NVIQ cognitive profile was more strongly associated with social and communicative deficits in autism than that of even, or VIQ>NVIQ profiles, the current findings reinforce conclusions that there is a subtype within a VIQ<NVIQ profile, in which individuals

can show high linguistic and pragmatic processing abilities. It is noteworthy here that some pragmatic deficits were in evidence even in the linguistically highly competent children; however, this finding is unsurprising in the light of the universality of pragmatic impairments in autism (Lord & Paul, 1997). In order to test the validity of this suggestion, further studies should attempt to replicate the current finding with clearly delineated, sizeable samples of children with VIQ<NVIQ, VIQ>NVIQ, and VIQ=NVIQ cognitive profiles.

Alternatively, the current findings showing universal global, pragmatic deficits in autism could perhaps be interpreted within the framework of the WCC theory. This is because pragmatic processing is a higher-level global function than that involving semantics in the linguistic domain. Therefore, it could be suggested that the high semantic processors exhibited weak central coherence, manifested by their inability to understand communicative intention with relatively difficult, sentence-level stimuli. According to this idea, weak central coherence could be identified in individuals with autism with seemingly normal central coherence (intact semantic ability), when a sufficiently high-level global task is used (pragmatics). However, the findings from the low semantic processors are problematic as they failed to show enhanced perceptual processing, despite exhibiting poor global processing ability. Thus, it is difficult to understand why supposedly weak central coherence would not result in better perceptual processing ability in these children. A further problem concerns the fact that pragmatic competence relies heavily upon meta-representational theory of mind abilities. Furthermore, it has been suggested that theory of mind deficits and weak central coherence result from impairments in separate underlying cognitive mechanisms in autism (Happé, 2001). So, the current pattern of results may indicate typical central coherence in the high semantic processors, but also suggest their pragmatic deficits resulted from separate meta-representational impairments.

To explain the findings showing that reduced global processing of semantics was not associated with enhanced perceptual functioning in the low semantic processors, one framework that may be well suited to explaining the current results is that provided by the neuroconstructivist models of development (Karmiloff-Smith, 1998; Karmiloff-Smith & Thomas, 2002). These models are particularly appealing as they can explain individual differences. Thus, rather than assuming that the findings of "spared" perceptual processing abilities in the low semantic processors, and "spared" semantic processing skills in the semantically competent children, reflected normal cognitive and neural functioning in these domains, as would be assumed by the WCC theory, a neuroconstructivist approach would propose that they are a product of fundamental differences in the neurocognitive development and brain organisation associated with autism, as well as individual level differences, due to unique learning experiences.

In conclusion, the findings presented in this chapter suggested that the developmental pathway in autism, that gives rise to good semantic ability, was associated with abilities in other domains, that is, pragmatic, linguistic, and perceptual skills. This lent support to the core idea of an interactional model of language acquisition (Bloom & Lahey, 1978; Tager-Flusberg, 1997; 1999), hypothesising that language is achieved by the integration of developments in several domains, such as conceptual, linguistic, and social arenas. Furthermore, as auditory discrimination abilities may be important for language acquisition in autism, future studies attempting to establish the causality in the present pattern of findings would be an important next step towards understanding the heterogeneity in the linguistic abilities seen in autism.

Chapter Nine

General Discussion

In the introduction to this thesis, the social and cognitive abnormalities associated with autism were outlined. An expansion in research in the past twenty years has greatly increased our understanding of the complex disabilities seen in individuals diagnosed with this disorder. Of particular relevance to the current studies have been investigations into the specific characteristics of the language impairment associated with autism. Such studies were outlined in the introductory chapter.

In order to make sense of this large body of research, numerous theoretical models of autism have been proposed. These accounts were outlined in the introductory chapter to this thesis, and the findings from the present series of experiments were interpreted within the framework of these various theoretical models, whenever possible. Two accounts, namely the weak central coherence (WCC) theory (Frith, 1989a; Happé, 1999), and the theory of enhanced perceptual functioning (EPF) (Mottron & Burack, 2001), have primarily attempted to explain non-social cognition in autism. These models have been valuable in explaining assets, as well as deficits, in autism. This is important, as autism differs from many other developmental disorders associated with intellectual impairment, in including enhanced abilities in specific domains as a frequently noted feature. The EPF theory proposed that the enhanced perceptual functioning in autism derived from an abnormal development of low-level perceptual processes, which was then assumed to compensate for a corresponding under-development in the higher-level cognitive processes that underpin global information-processing. Thus, this model can explain the good performance of individuals with autism in perceptual tasks, whilst deficits in such individuals are assumed to reflect abnormalities in domain-general processes. However, no direct discussion of the implications for social and communicative deficits are provided in this model; instead, the focus is upon explanations of the enhanced perceptual performance seen in those with autism. The WCC theory describes atypical information-processing in autism at different levels of complexity (Happé, 1999). Evidence for the presence of weak central coherence in autism has been found at the low visual-perceptual, and the high verbal-semantic levels. Studies that have attempted to determine whether this cognitive style characterises auditory-perceptual processing in autism have yielded inconsistent results. The problem being that "global" processes have been operationalised differently across studies. Happé (2001) has suggested that central coherence is important for social and communicative functioning, as the theory of mind must be fed by relevant, coherent social input. She nevertheless suggests that deficits in central coherence and theory of mind abilities represent separate abnormalities in autism. Relevance theory of human cognition and communication (Sperber & Wilson, 1995) embraces the theory of mind hypothesis in proposing that intentions and communication are intrinsically linked. Happé (1993) successfully applied this framework in a study, where the meta-representational ability of children with autism was directly examined in relation to their understanding of similes, metaphors, and irony. Whilst the findings showed that the children's theory of mind ability explicitly predicted their level of communicative competence, important questions about the atypical perceptual processing seen in autism, as well as the potential impact of such features of autism on social communicative processes, were not addressed. Two recent models of autism, that consider the abnormalities of the disorder to be social in origin, are the componential model of theory of mind (Tager-Flusberg & Sullivan, 2000; Tager-Flusberg, 2001a) and the enactive mind theory (Klin, Jones, Schultz, & Volkmar, 2003). The componential theory of mind model rests upon the notion that theory of mind is a developmental concept, comprising several interacting perceptual and cognitive mechanisms that are involved in social information-processing from very early on in development. However, whilst this account is limited to the social domain, the enactive mind model posits that the markedly reduced salience of social stimuli in autism leads to enhanced specialisations being formed to process a range of physical stimuli, instead of in the social domain. The social deficits that are fundamental to the disorder are proposed to influence the developmental trajectory from the earliest stages of development, and result in social knowledge being constructed outside the social domain. Thus, this theory provides a considerably more holistic and developmentally based account of autism, than those focusing purely on social, or on non-social cognition. A further appealing feature of this account is that it is highly consistent with models of typical development, that highlight infants' predisposition to attend to social stimuli, and explain the ways in which this serves to shape brain organisation (Elman, Bates, Johnson, Karmiloff-Smith, Parisi, & Plunkett, 1996; Johnson, 2000; 2001). Thus, according to this theory, a reduction of this tendency results in finely-tuned specialisations in non-social domains.

In chapter one, the sensitivity to pitch contour information in speech, speech-like, and musical stimuli in children with autism was investigated. The first experiment presented in this chapter showed a generally enhanced ability to extract pitch information from speech and synthesised speech stimuli in those with autism. However, as both the children with autism and their controls showed superior performance with the intact speech, as compared with the synthesised speech stimuli, the impoverished speech condition failed to elucidate the role of semantic content in speech, in relation to processing perceptual-level information. Thus, this condition was replaced with musical contours in experiment two. As the findings from the first experiment were consistent with previous studies showing enhanced processing of musical pitch in autism, it was hypothesised that there may be generally enhanced pitch processing across speech and musical domains in autism. An important finding from experiment two showed a significant positive correlation between performance in the speech and music conditions for the children with autism, whilst this was not found for the control children. Furthermore, the children with autism exhibited superior processing of pitch information in both conditions, as compared to their controls. Experiment two also included a semantic processing measure, in which the children with autism performed at significantly lower levels than their controls. Taken together, these findings appeared to be consistent with the WCC theory (Frith, 1989a; Happé, 1999) and the EPF theory (Mottron & Burack, 2001). However, an inspection of the data from the individual children in the autism sample showed that, whilst more than half of the children showed enhanced perceptual processing, and almost half showed poor semantic processing, less than a third of the children in the autism sample exhibited a processing profile that was consistent with the predictions of the WCC and EPF theories. Another interesting finding showed that a further third of the children with autism exhibited enhanced perceptual processing alongside competent semantic processing.

This pattern of findings was further investigated in experiment three. This study was designed to directly address the question of whether a bias towards perceptual level information would co-exist alongside compromised semantic processing in autism. The identification of the different types of subgroup performance in experiment two necessitated the exploration of alternative frameworks to those provided by the WCC and EPF theories. Therefore, rather than predicting generally enhanced perceptual or local processing, differences were predicted in the processing of social versus non-social stimuli, between children with autism and their controls. The finding from experiment two had shown that children with autism, unlike their controls, exhibited a domain-general ability to extract pitch patterns from speech and musical stimuli. It was thus anticipated that the findings from experiment three would elucidate the consequences of a hypothesised reduction in the early biased sampling of socially relevant information in autism. The findings from the study showed that when required to interpret speech stimuli on the basis of either their perceptual or semantic properties, children with autism, as well as their controls, showed a semantic processing bias. However, this bias was significantly weaker in autism than that seen in the control children. Secondly, children with autism exhibited an enhanced perceptual bias in comparison to their controls, and made significantly more perceptual judgements of the speech stimuli, than their controls. The perceptual accuracy data was striking, and the autism group showed highly superior performance. Although the finding of intact semantic processing ability appeared to contradict the findings from experiment two, where semantic deficits were observed, it should be noted that the experimental paradigm used in experiment three did not include forced choice. Here, participants with autism made significantly fewer semantic choices than the control children, and accuracy data consisted of a small number of self-selected semantic items. It is therefore likely that semantic impairments were masked in this study.

Experiment four built upon the previous findings of reduced semantic speech processing bias in autism, and proposed an abnormal modularisation hypothesis. This study tested auditory pitch discrimination abilities across speech and music domains. The findings from this experiment failed to support either the WCC or EPF theories, as children with autism did not show enhanced performance, relative to matched controls, in the condition where both stimulus pairs were musical. The most striking finding was that the children with autism showed an equal ability in discriminating subtle changes in pitch sequences, when comparing both speech-speech and music-music, as well as cross-domain speech-music stimulus pairs. In contrast, the control children were only capable of performing such comparisons with the music-music stimuli. Thus, these findings lent support to the experimental hypothesis, stating that the reduction in the early biases towards social information in autism will result in decreased neural specialisations developing in the social, speech domain.

Whilst previous studies had focused upon pitch processing, experiment five was directed at examining the sensitivity to rhythmic information in speech stimuli in children with autism. The rationale was derived from evidence showing selective pitch and rhythm dissociations in individuals with congenital language disorder (Alcock, Passingham, Watkins, & Vargha-Khadem, 2000). As very little is known about rhythmic processing abilities in autism, it was important to rule out any deficits that have a potential to contribute to their language disorder. The findings from this study did not provide any evidence for deficits that would be likely to impact upon speech processing. The findings also failed to support either the WCC or EPF theories, as they indicated that children with autism did not show superior discrimination of rhythm in pseudo-speech stimuli, when compared to their controls. However, as those with autism were significantly better at extracting rhythm patterns from intact speech stimuli than their controls, the findings were taken as support for the abnormal modularisation hypothesis. Furthermore, this study included a similar semantic measure to that used in experiment two, and again similar patterns of subgroup performance within the autism sample were in evidence, to those seen in experiment two. Strikingly, only 14 per cent of children showed a processing profile that was consistent with the WCC and EPF theories, and over a third of the children showed enhanced perceptual processing alongside high semantic ability.

As the findings from experiments one, two, three, four, and five showed clear abnormalities in the processing of pitch and rhythm in speech in autism, together with semantic deficits in some children, it was of interest to test the children's understanding of the global function of prosodic cues in a psycholinguistic framework. For this purpose, the PEPS-C prosody test battery (Peppé, McCann, & Gibbon, 2003) was administered to the children. A further rationale for including this test battery was that the findings from experiments four and five suggested that the atypical perceptual processing in autism was more social in origin than is allowed for by either the WCC or EPF theories. Indeed, an early substantial reduction in the salience of speech information would be expected to result in atypical language development in autism (Klin et al., 2003). The results from the PEPS-C test battery showed compromised prosodic understanding in autism, compared to age- and intelligence matched controls. In the receptive domain, children with autism were impaired in perceiving prosodic differences at the phrasal level, in understanding vocally expressed affect, and in identifying chunking. In contrast, they were able to understand contrastive stress, to perceive intonational differences at the single-word level, and to understand declaring and questioning intonation at similar levels to their age- and intelligence matched control children. In the expressive domain, children with autism showed deficits in disambiguating syntactically ambiguous phrases by their phrase boundaries, and in producing declaring and questioning intonation. No group differences emerged in the ability to express affect vocally, to produce contrastive stress, or to imitate intonational and prosodic forms at either the single-word or the phrasal level. However, the findings again showed significantly poorer prosodic expression in children with autism, as compared to their control children. An important finding from the analyses carried out between experimental data on perceptual processing, and the PEPS-C prosody scores, showed that children with autism appeared to rely on qualitatively different mechanisms to the controls when processing prosody. Specifically, whilst the control children relied strongly upon verbal and non-verbal intellectual abilities when processing prosody, enhanced perceptual discrimination skills were central to prosodic understanding in autism. Such abilities were not related to prosodic competence in the controls. These findings suggested that the participants with autism applied their enhanced perceptual skills to disambiguate the meaning of prosody. A surprising finding was that the children with autism exhibited intact understanding of declaring and questioning intonation. Within the framework of Relevance theory (Sperber & Wilson, 1995), the understanding of communicative intention conveyed by questioning intonation is considered to require second-order theory of mind ability; thus, deficits would have been expected in this area in autism.

The finding of intact pragmatic understanding of intonation in autism was extended to communicatively more valid analogous stimuli in experiment seven. In order to examine whether the information-processing style of the children with autism could inform our understanding of their meta-representational abilities, the findings were discussed within the framework provided by Relevance theory (Sperber & Wilson, 1995). Relevance theory suggests that whilst the understanding of informative intention of declarative utterances is a first-order meta-representational process, the comprehension of communicative intention in prosodically cued questions requires second-order meta-representational reasoning. The children's total receptive score from the PEPS-C test battery was used as an index of their level of pragmatic ability. The findings from this more stringent, ecologically valid experiment showed that marked deficits were apparent, even in intellectually and linguistically able individuals with autism, in this area of prosody. Specifically, whilst the pragmatic ability of many children with autism was sufficient for understanding communicative intention at the single-word level, it was insufficient for comprehending such intention at the sentence-level. The deficit in pragmatic understanding was manifested as a declarative bias, whereby children with autism erroneously classified most utterances on the basis of their informative, literal intention only. These findings supported the predictions of Relevance theory, and suggested that these children utilised verbal scaffolding and general reasoning skills, in order to "hack" out solutions to prosodic problems (see Happé, 1995; Happé, Ehlers, Fletcher, Frith, Johansson, Gillberg, Dolan, Frackowiak, & Frith, 1996). Anecdotal evidence suggested that children with autism had been primed to look out for "Wh" question words, when attempting to determine whether an utterance was a question or a statement. When such literal cues for question utterances were absent, as was the case in the present study, a robust tendency to categorise all utterances as declarative was seen in the participants with autism. In addition to Relevance theory, these findings were also consistent with several other theoretical models, such as the componential model of theory of mind (Tager-Flusberg, 2001a) and the enactive mind model (Klin et al., 2003).

As high levels of heterogeneity in both linguistic and perceptual abilities were in evidence in the autism sample tested throughout this thesis, the final research question concerned how semantic processing ability in verbal children with autism might relate to such individuals' perceptual and pragmatic abilities. Thus, the final chapter eight was aimed at examining the children's processing from the low auditory-perceptual through to the highest pragmatic-linguistic level. The findings showed that in the subgroup of children with the highest semantic ability, co-occurring superior auditory-perceptual and pragmatic skills were in evidence. These findings supported the results obtained from the PEPS-C test battery, suggesting that enhanced perceptual abilities were related to the acquisition of higher-level linguistic and pragmatic competence in autism. Furthermore, the results were consistent with theoretical models of language development (Bloom & Lahey, 1978; Tager-Flusberg, 1997; 1999), one of which proposes that language acquisition represents interacting developments in the social, linguistic, and conceptual domains. This was a striking finding as the verbal and non-verbal characteristics of the children with the highest and the lowest semantic processing ability did not significantly differ. However, as verbal intellectual abilities were only assessed using the British Picture Vocabulary Scale (Dunn, Whetton, & Pintilie, 1997), it is unsurprising that performance in this test of receptive vocabulary was not associated with the children's higher-level linguistic abilities. It was suggested that the enhanced auditory-perceptual abilities of the high semantic processors may have been important in their acquisition of language. As a small study has identified low-level auditory processing impairments in autism (Plaisted, Saksida, Alcántara, &

Weisblatt, 2003), it was suggested that the low semantic processors may have presented relatively more severe deficits in this area. Indeed, one theory of specific language impairment (SLI) predicts that such individuals' primary deficit is auditory, rather than linguistic, in nature (Tallal, 2000). Thus, further studies are needed to identify the role of auditory discrimination abilities in language acquisition in autism. A further important finding showed that, whilst the lowest semantic processors exhibited relative strengths in processing perceptual information in speech, as compared with music, the highest semantic processors showed the opposite pattern of performance. This indicated that the semantic processing ability of the highest semantic processors was associated with acute perceptual discrimination abilities in the musical, as compared to the speech domain. The impoverished semantic ability of the low semantic processors resulted in the opposite pattern of processing, possibly reflecting the more frequent occurrence of speech, as compared to music, in the environment. The findings from these analyses failed to support the predictions of either the WCC or the EPF theories, as neither subgroup showed patterns of performance that conformed to the predictions of these models. Therefore, these results were interpreted within the framework of the neuroconstructivist models of development (Karmiloff-Smith, 1998; Karmiloff-Smith & Thomas, 2002), as these can explain individual differences that derive from each individual's unique learning experience. Furthermore, such models do not consider the ostensibly "spared" abilities in autism to reflect typical neural and cognitive function, but suggest that they are attained via a fundamentally different developmental trajectory.

The discussion of the findings from the experiments presented in this thesis show that, whilst theoretical models capture and elucidate many of the features seen in autism, they nevertheless provide relatively fractionated explanations of very specific aspects of the disorder. Thus, whilst the WCC and EPF theory have been successful in explaining findings from perceptual studies, they fail to provide a detailed, coherent account for why social and communicative abnormalities should co-exist alongside enhanced perceptual processing in autism. The subgroup findings presented in chapters two, five, and eight, in this thesis, clearly highlight the immense variation in the extent to which individuals with autism show the cognitive profile that is associated with the WCC and EPF accounts. Indeed, it was found that the performance of less than a third of the children in the autism sample conformed to the characteristic information-processing style predicted by the WCC and EPF theories. Importantly, the findings further suggested that, for a minority of individuals with autism, enhanced auditory-perceptual functioning might facilitate language acquisition, in which case finely-tuned perceptual abilities do not arise at the expense of global processing abilities.

A major appeal of the enactive mind model (Klin et al., 2003) concerns its suggestion that an early reduced tendency to selectively attend to social stimuli is causal in terms of the atypical perceptual processing seen in autism. According to this account, attention is instead directed towards non-social stimuli, resulting in heightened specialisations being formed in the physical features of stimuli and the environment. However, even if infants with autism do show atypical processing of socially relevant information, development still occurs in environments, that are rich in social stimuli. Parents, siblings, and carers of infants with autism talk to these babies, and it is clear that some aspects of speech stimuli are processed and represented by those with autism. The varying degrees to which this is achieved is reflected in the high levels of heterogeneity in the language and social abilities seen in autism. For example, the data obtained from the PEPS-C prosody battery, presented in chapter six, showed that a considerable proportion of children with autism performed similarly to their controls. Thus, at this level of investigation, these children with autism showed seemingly "normal" language abilities. Consistent with this are the subgroup findings of Kjelgaard and Tager-Flusberg (2001), where evidence of a "normal" language subtype of autism was observed. In this thesis, a subgroup of children with autism with advanced linguistic skills, adept perceptual processing, and good non-verbal intellectual abilities were identified. However, when these individuals were asked to determine whether an utterance was a question or a statement on the basis of its intonational contour, a strong tendency to judge these stimuli on the basis of their semantic content alone was observed. This resulted in a declarative bias. This finding clearly shows that difficulties in pragmatic understanding are a universal characteristic of the language of even the most able individuals with autism.

One hypothesis that arises from the model proposed by Klin and his colleagues (2003) is that knowledge acquired and constructed within the social domain will be qualitatively different to knowledge that is a direct product of intact perceptual abilities and excellent problem-solving skills. Another component of this model is that an atypical focus of attention might result in specialisations being developed in the non-social domain. Thus, similar outcomes to those predicted by the WCC and EPF theories would be expected. However, whilst enhanced perception has been frequently reported in the autism literature, in the present series of experiments this was not found to be so in all cases. For example, in experiment four, it was found that children with autism failed to show superior performance to their controls in a stimulus condition that included musical discrimination. This highlights the point that typically developing children, and those with moderate learning difficulties, can also show adept musical processing. The interesting finding here, however, was that the children with autism were able to maintain high levels of performance when the stimuli incorporated linguistic components, whereas the performance of the control children rapidly deteriorated when the stimuli were speech, and ceased to be purely musical. The findings from this study suggest that an atypical modularisation, rather than an enhanced perceptual functioning model, characterises autism. Further limitations of the non-social, perceptual accounts of autism are highlighted by an absence of group difference in the rhythm task of experiment five, together with the significant variance in performance amongst the children with autism. Thus, as the findings from the experiments presented in this thesis illustrate, enhanced perceptual discrimination abilities are not a universal feature of autism.

As was suggested in chapter eight, future research should link into the studies on language subgroups in autism (Kjelgaard & Tager-Flusberg, 2001), and investigate the role of auditory-perceptual processing abilities with regard to language acquisition. This would provide a coherent approach to studying the phenotype in autism.

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Appendix one

Table Showing Participation in the Various Experiments

Participant code	Exp. 2	Exp. 3	Exp. 4	Exp. 5	PEPS-C	Exp. 6
ASD1 (HFA)	x	x		x	x	x
ASD2 (LFA)	x	x	x		x	x
ASD3 (HFA)	x	x		x	x	x
ASD4 (HFA)	x	x	x	x	x	x
ASD5 (HFA)	x	x	x	x	x	x
ASD6 (LFA)	x	x	x	x	x	x
ASD7 (HFA)		x		x		x
ASD8 (HFA)	x	x	x		x	x
ASD9 (HFA)	x	x	x	x	x	x
ASD10 (HFA)		x				x
ASD11 (HFA)	x	x	x	x	x	x
ASD12 (HFA)	x	x	x		x	x
ASD13 (HFA)	x	x	x		x	x
ASD14 (HFA)	x	x	x		x	x
ASD15 (HFA)		x		x		x
ASD16 (LFA)	x	x		x	x	x
ASD17 (HFA)	x	x	x	x	x	x
ASD18 (HFA)	x	x	x		x	x
ASD19 (LFA)	x	x	x	x	x	x
ASD20 (HFA)	x	x	x		x	x
ASD21 (HFA)	x	x	x		x	
ASD22 (LFA)	x	x				
ASD23 (LFA)	x	x				
ASD24 (LFA)	x	x				
ASD25 (LFA)		x				
ASD26 (LFA)	x	x				
ASD27 (LFA)		x				
ASD28 (LFA)		x				
ASD29 (HFA)	x			x	x	
ASD30 (HFA)	x		x	x	x	
ASD31 (HFA)	x		x	x	x	
ASD32 (HFA)				x		
ASD33 (HFA)				x		
ASD34 (LFA)				x		
ASD35 (LFA)			x			
ASD36 (HFA)			x			
ASD37 (HFA)			x			
ASD38 (HFA)			x			
ASD39 (HFA)			x			
ASD40 (HFA)			x			
ASD41 (LFA)				x		
ASD42 (LFA)				x		
ASD43 (LFA)				x		