Colour Processing in Autism Spectrum Disorders

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ABSTRACT

The research described in this thesis investigated colour processing in children and adolescents with autism spectrum disorders. Although idiosyncratic responses to colour have been widely reported in autism (William, 1999; White & White, 1991), and therapeutic interventions involving colour are frequently used with individuals with this disorder (Howlin, 1996; Irlen, 1991), few controlled colour processing investigations have been carried out. The experiments reported in the thesis have two main points of focus. Firstly, the therapeutic effects of colour overlays on different aspects of cognition were tested, and secondly, studies into colour discrimination, memory, naming and categorisation were carried out in order to evaluate the role of language and perceptual processing in colour processing. In experiments one and two it was established that significantly more children with autism than age and intelligence matched controls improved their reading speed when using a colour overlay. In experiments three and four, these effects were further investigated using visual change detection and reading comprehension tasks with and without colour overlays. Again, a significant improvement in performance was noted in the autism group when using colour overlays. The results from experiments four to eleven, testing colour discrimination, memory and naming failed to confirm atypical colour processing in autism, although the findings did suggest that cognitively unimpaired children with autism showed sharper category boundaries than those with autism and cognitive impairment and typically developing controls. Finally data from a case study of a boy with Asperger Syndrome who showed highly idiosyncratic colour responses were presented. The findings from the studies are discussed within the context of current theories of visual cognition in autism and theories of colour perception.

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DEDICATION

This thesis is dedicated to my fabulous family (Mum, Dad and sister) whose ongoing support and love made the PhD a reality.

To those members of my family who have passed away (all my much missed grandparents), I hope I have made you proud.

"I looked through the window at the garden outside, Instead of looking from tree to tree and shrub to shrub, I saw one whole picture at once: one whole garden. More than this, though, I saw the view through the window as no longer a picture. It looked like a place – not just theoretically but visually. It looked as if I could just walk straight out there, not 'with' things but among them. What I had had to learn in theory, I could now see in perception. I'd learned that the world had available depth to be experienced in moving through it, but I'd never actually consistently or properly seen that variation. Now I had merely to look at something to know it as it was."

Donna Williams (1999) – an excerpt from her novel "Like Colour to the Blind" (p150), describing the first time she wore colour glasses.

CHAPTER ONE

INTRODUCTION

The studies presented in this thesis aim to investigate colour processing in children with autism spectrum disorders. There are few reported studies in the literature investigating colour processing in autism, and so little is known about the way in which these children process colour information. The rationale for the studies presented in this thesis is derived from three main sources. First, idiosyncratic responses to colour information have been widely reported in autism. Second, it has been suggested that colour may be used in therapeutic intervention for children with autism. For example, Howlin (1996) has highlighted the use of colour in light therapy, and Irlen (1991) has suggested that the use of colour overlays and tinted lenses may reduce symptoms of visual stress in children with autism. Third, an aspect of autism that has aroused considerable interest concerns enhanced perceptual information processing. Indeed, several prominent theoretical accounts of autism propose that many aspects of the disorder arise from such a basic abnormality in information processing. It is hoped that the study of colour perception in autism will serve to inform both therapeutic approaches to autism, and will also extend out understanding of atypical perceptual processing

Characteristics of Autism Spectrum Disorder (ASD)

Autism is characterised by deficits in social interaction, verbal and nonverbal communication, and in imaginative activity with a markedly restricted repertoire of activities and interests (Diagnostic and Statistical Manual of Mental Disorders; DSM-IV 1994). DSM-III (1980) included abnormal responses to sensory stimuli (Gillberg &

Coleman, 1992). However, this was omitted in later formations (O'Neil & Jones, 1997) due to confusion over the level of description of the symptoms (Ornitz, 1989). For example, unusual responses to sound tend to be thought of as a symptom of disordered language (Rutter & Lockyer, 1967) rather than a discrete sensory problem in its own right. Similarly, painful hypersensitivity or an obsession with particular textures has been grouped under the heading of 'responses to the environment' or 'affective response' (Volkmar, Cohen & Paul, 1986).

Whilst sensory processing abnormalities are not currently included in DSM-IV as diagnostic criteria, numerous authors refer to a high incidence of sensory processing abnormalities in autism (Dawson, 1983; Filipek, Accardo, Baranek et al., 1999; Gillberg & Coleman, 1992; Mayes & Calhoun, 1999). Indeed, based on a review of research findings, first hand reports and clinical accounts, it has been suggested that between 30-100% of children with autism spectrum disorders have sensory perceptual abnormalities of some kind (Dawson & Watling, 2000).

Reported abnormal responses to sensory stimuli within the autism spectrum have included hyposensitivities (lowered response), hypersensitivities (heightened response), sensory distortions (misrepresentation of individual surroundings), sensory tune outs (sound or vision may dim or black out temporarily), sensory overload (input to more than one sense modality causes stimuli confusion) and multi-channel perceptions (experiences of synaesthesia) (O'Neil & Jones, 1997). Such responses have been reported in response to tactile (Cesaroni & Garber, 1991; Joliffe, 1992), auditory (Cesaroni & Garber, 1991; Dahlgren & Gillberg, 1989; Khalfa, Bruneau, Rog et al., 2001 Ornitz, 1974), olfactory and gustatory (Kientz & Dunn, 1997), vestibular (Hatch-

Rasmussen, 1995), multisensory processing (Williams, 1999), and visual stimuli (Irlen, 1991; Kientz & Dunn, 1997; Williams, 1999).

Sensory modulation refers to the ability to filter or attend selectively to sensory information. Some researchers have speculated that this is the primary symptom of autism from which other symptoms can be understood (for example Ornitz, 1989). For instance, children with autism demonstrate an obsessive desire for the preservation of sameness and will notice minor changes in their environment that to others seem small and insignificant (Happé, 1994). A simple rearrangement of a piece of furniture or being driven via a different route to school can be very distressing for a child with autism (Kanner, 1943; Happé, 1996). This resistance to change and dependency on rigid rituals is thought to be a result of avoidance of disturbing sensory input. In typically developing individuals, sensory overload has been related to changes in attention (Hockey, 1970), social withdrawal (Gottschalk, Hare & Bates, 1972) and ritualistic behaviour (Rago & Case, 1978). Similarly in autism, correlations have also been noted between unusual sensory processing and social aloofness (Dawson, 1983; Wing & Attwood, 1987), and Saulinder, Fein and Liss (2001) found that sensory underreactivity was most strongly associated with impaired socialisation skills.

Baranek (1999) has suggested that early identification of abnormal sensory motor-processes could aid the early identification of autism (Baranek, 1999). In agreement with this are Gillberg, Ehlers, Schaumann et al. (1990) who suggest that if autism is to be recognised in infancy, then the focus of research needs to be shifted from the typical speech/language problems to recognition of these abnormal perceptual responses (Kanner, 1943; Grandin & Scariano, 1986; Myles, Cook , Miller et al., 2000).

However, research addressing speech and language problems is also important as this is usually the first indicator that a child may fall within the spectrum (Howlin & Goode, 1998; Lord & Paul, 1997), and impaired communication can often cause family members the most concern (Bristol, 1984). Follow-up studies of children with ASD have revealed that language and communication problems are persistent and closely related to both subsequent prognosis (Howlin, Mawhood & Rutter, 2000; Mawhood, Howlin & Rutter, 2000; Szatmani, Bryson, Boyle et al., 2003) and challenging behaviour (Sigafoos, 2000; Van Berckelaer-Onnes, Van Loon & Peelen, 2002).

All individuals with ASD show qualitative impairments in verbal and non-verbal communication, irrespective of their level of functioning, and approximately one third to one half of those with a diagnosis of an autistic disorder never acquire speech (Bryson, 1996; Lord & Paul, 1997). Those who do develop speech, however, show a very uneven pattern across the different areas of language. Phonology appears to be relatively spared in individuals with ASD, although vocal quality, intonation and stress patterns are strikingly atypical (Lord & Paul, 1997; Tager-Flusberg, 2001). No specific impairments in syntax are reported (Kjelgaard & Tager-Flusberg, 1999; in Tager-Flusberg, 2001) and similar patterns of performance within the ASD population are found in grammatical development and levels of achievement (Tager-Flusberg, 2001).

Semantic development in particular is one area that has been shown to be problematic in ASD, and some of the problems exhibited include immediate and delayed echolalia, pronoun reversal, the use of metaphors and neologisms, and difficulties with figurative languages (Howlin, 1999; Jordan, 1999; Lord & Paul, 1997). Although vocabulary acquisition may be good in some individuals with ASD, certain classes of words, such as social-emotional terms, are underrepresented (Tager-Flusberg, 2001), and problems in comprehension are more frequent than would be expected on the basis of expressive vocabulary ability (Lord & Paul, 1997). Pragmatic difficulties are shown in both non-verbal and verbal communication, and deficits in conversation, discourse and narrative are common amongst high functioning individuals (Losh & Capps, 2003; Tager-Flusberg, 2000).

There are several theoretical constructs that are used to explain the specific behavioural patterns of individuals with ASD. The three most influential accounts have included theory of mind, executive functions and central coherence. The theory of mind hypothesis has attempted to explain the social-communicative problems of people with ASD in terms of a specific disability in attributing mental states to themselves and others (Baron-Cohen 1995, 2000; Baron-Cohen, Leslie & Frith, 1985). Theory of mind (TOM) tasks often involve understanding and predicting behaviour based on false belief. An example of this is the classic Sally-Ann task (Wimmer & Perner, 1983). In this task the child is shown two dolls, one called Sally and one called Ann; Sally has a basket and Ann has a box. The child watches as Sally places her marble in the basket and goes out. Whilst away, Ann moves Sally's marble from the basket to her own box and then goes out. When Sally returns, the children are asked where she will look for her marble. In order to pass the task, children must appreciate Sally's false belief. Given that the communicative deficits in autism profoundly impact on the lives of these individuals, it is unsurprising that research efforts have focused in this area. However, this has meant that many non-social features remain largely unexplained (Happé, 1999; Plaisted, 2000). The non-social features of autism are rather varied, but include a restricted repertoire of interests, repetitive and obsessive behaviours, rigidity and perseveration as well as uneven development of skills and intelligence.

Substantial evidence suggests that autism can be reliably diagnosed on the basis of early social responsiveness seen in play, joint attention and imitation (Lord, 1995; Moore & Goodson, 2003) at around two years. In order to reach criteria for diagnosis, symptoms of autism must be in evidence before the age of three years (APA, 1994; WHO, 1992). However TOM abilities are apparent in typically developing children at approximately the age of four, and therefore symptoms of autism are present before TOM develops (Tager-Flusberg, 2001a). This then raises serious questions about the relationship between TOM deficits and the social and communication problems found in autism. Further, experimental studies have shown that individuals with a clear diagnosis of autism can succeed on TOM tasks (Charman, 2003), without showing corresponding levels of spontaneous social adaptation (Bowler, 1992; Klin, 2000). As Klin (2000) has suggested, the 'all or nothing' nature of the task results in dichotomous data (e.g. passers and failers) for abilities that are better conceptualised as dimensional. Additionally, TOM tasks are often presented in an explicit, verbal problem-solving format which bears little resemblance to naturalistic social situations.

Executive function is an 'umbrella' term for a broad array of mental operations. This theory has sought to explain the diagnostic features of autism as arising from deficits in regulating behaviour through planning, monitoring and inhibiting attention. Functions are believed to be mediated by the frontal cortex (Hill, 2004). Several independent studies have found evidence of poor performance based upon measures of executive function in children and adolescents with autism (Hughes, Russell, & Robbins, 1994;

Ozonoff, Pennington & Rogers, 1991). The most robust finding from executive functioning research is that individuals with ASD tend to make perseverating errors and have problems with set-shifting and planning (Griffith, Pennington, Wehner et al., 1999; Liss et al., 2001). Executive dysfunctioning is able to explain some of the non-social deficits in ASD, such as repetitive and stereotyped behavioural patterns (Bailey, Lecouteur, Gottesman et al., 1995) but is unable to provide an explanation for the islets of ability and areas of superior functioning often seen in these individuals. In order for executive function deficits to be considered a diagnostic marker, deficits should be universal (Hill, 2004), and yet several studies have shown no evidence of executive function deficits in individuals with autism (Baron-Cohen, Wheelwright, Stone et al., 1999; Hill & Russell, 2002). Executive function deficits have also been found in other neurodevelopmental disorders such as attention deficit hyperactivity disorder (ADHD) (Pennington & Ozonff, 1996).

Most pertinent to the research described in this thesis are theories of autism that attempt to account for atypical perceptual processing. These include the weak central coherence theory (WCC) (Frith, 1989; Happé, 1999), the enhanced perceptual functioning theory (EPF) (Mottron & Burack, 2001) and the reduced generalisation hypothesis theory (RG) (Plaisted, 2001).

The WCC theory proposes that autism is characterised by a processing bias in favour of local features at the expense of global, context dependent meaning or Gestalt. Thus the performance of individuals with autism on such tasks as the block design test from the Weschler Intelligence Scales (Happé, 1994), and the embedded figures test (Witkin, Oltman, Raskin et al., 1971) which requires participants to process the local parts of the stimuli and neglect the context in which the stimuli is presented, is frequently found to be better than that of intelligence and age matched controls (Jolliffe & Baron-Cohen 1997; Shah & Frith, 1993).

The term 'high level' WCC has been used to explain findings from studies of contextual/verbal-semantic processing in which individuals with autism frequently perform poorly (Plaisted, Saksida, Alcantara & Weisblatt, 2003). For example, participants with autism have been found to read fewer homographs correctly in context than matched controls (Frith & Snowling, 1983, Happé, 1996). In an early study, Hermelin and O'Connor (1967) had shown that children with autism differed from developmentally delayed children in being unable to group items according to category in order to increase memory, and more recently Tager-Flasberg (1991) found that semantic similarity in lists of nouns did not facilitate immediate free recall in participants with autism. Further, in a study with able participants with autism, Jolliffe & Baron-Cohen (1999) found that they were unable to draw bridging inferences between sentences.

In an attempt to explore WCC at low perceptual levels, Happé (1996) asked individuals with autism to make simple judgements about standard textbook visual illusions. Illusions can be analysed into a 'to-be-judged' figure and an inducing context or ground (Gregory, 1997). Happé reasoned that if people with autism have a tendency towards fragmented perception and focus on the to-be-judged parts without integrating them into the surrounding illusion-inducing context, one might expect them to succumb less to the typical misperceptions. The findings supported the hypothesis, and showed that people with autism were more likely to make accurate judgements about the illusions than typical and mental age matched controls. This superior ability in autism appeared to be related to disembedding skill, since when the figures were artificially disembedded (by highlighting the to-be-judged parts with raised coloured lines) control groups performed as well as the autism group. However, Ropar and Mitchell (2001) failed to replicate this finding when using a more sophisticated methodology. Their study differed from that of Happé in that participants manipulated the elements in the display about which they were to make judgements and verbal responses were not made. The autistic group showed no advantage on this task, and the data analysis showed that performance on this task did not correlate with scores from other visuospatial tasks believed to measure weak central coherence.

Jarrold and Russell (1997) found that individuals with autism showed less facilitation than controls on a counting task when items were displayed in the canonical groupings used on dice. The authors interpreted these findings as showing that the participants in the autism group counted each dot separately, without attention to their global configuration, and thereby supported the notion of low level weak central coherence.

Hobson, Ouston, and Lee (1988) and Langdell (1978) have shown that children with autism are less affected by inversion of faces in recognition tasks. In inverted faces, the configural features are disrupted and the ability to recognise them suggests a feature-based processing style for faces in autism. This may also account for their deficits in processing emotional (versus identity) information (McKelvie, 1995). A more recent study suggests that individuals with autism are not unable to form configuration-based face representations, but are less likely to use contextual information in perceptual tasks (Teunisse & de Gelder, 2003). Similar findings have emerged from linguistic processing tasks (e.g. Jolliffe & Baron-Cohen, 1999). Neurological studies have provided evidence for abnormal face processing in autism. For example, McPartland, Dawson, Webb et al., (2004) found slowed neural speed of face processing in autism, and Pierce, Muller, Ambrose et al., (2001) found that the fusiform face area did not show consistent activation in response to face stimuli in participants with autism.

Superior performance in autism relative to controls has been demonstrated in a series of visual search tasks. In a visual features task, the participant is required to detect a target item that differs from distractor items along a single dimension (e.g. searching for a red X target among red T and green distractors). Studies have shown that children with autism were better than normally developing children, matched for age and general ability, at detecting a pre-specified target hidden among simultaneously presented distractors (O'Riordan, Plaisted, Driver et al., 2001; Plaisted, O'Riordan & Baron-Cohen, 1998a). Another example comes from studies using the Navon task, in which large letters composed of small letters are presented. Subjects are required to report to either the local or global letter, in conditions where these are congruous (matching) or incongruous (non-matching). The usual finding is that normal subjects show a global advantage (they are faster to name the big letters than the small) and global effect is processed first. Ozonoff, Strayer, McMahon et al., (1994) failed to find a local advantage or precedence effect in the group with autism, although this effect may have been caused by the unusually long exposure times used in the study (Jolliffe and Baron-Cohen, 1997). However, this is unlikely since Mottron, Burack, Stauder et al., (1999) also failed to find a local advantage or precedence effect in autism when using brief presentation times. Indeed their findings showed a specific global advantage in autism.

Pellicano, Gibson, Maybery et al., (2003) also provide evidence for the WCC theory. Children performed two visual search tasks, a global dot motion task which required coherence, and a flicker sensitivity task which did not, as well as additional measures of coherence. The findings showed that children with autism were only significantly worse than controls on the visual tasks requiring coherence.

Few studies have attempted to study WCC across domains in the same sample of children. Such a study was carried out by Hoy, Hatton & Hare (2004), who compared the performance of age and ability matched typically developing children and children with autism on the visual illusion task (Happé, 1997), and a homophone task resembling the homograph task (Frith & Snowling, 1983). The homophone task had two conditions (common homophones versus rare homophones). Children were told that they would hear a short story and would be shown some pictures. They were told to listen very carefully to the story, as it would allow them to find the picture of one of the words in the story. They were then read a short ambiguous sentence followed by the appropriate unambiguous sentence. They were then shown the card with the appropriate pictures and a correct response was scored if the child selected the correct representation. Consistent with the findings of Ropar & Mitchell (1999; 2001), both the autism and control groups were fooled by the visual illusions relative to control items. Therefore findings from the visual illusion task are not supportive of WCC, as the children did not show an enhanced ability to ignore inducing context of illusions. The group with autism only made significantly more errors on the rare condition of the homophone task, and further analysis revealed this was due to difference in BPVS verbal ability scores rather than diagnosis status. If the tasks used in this study are genuine measures of central coherence at the verbal and visual level, than the results failed to support the view that weak central coherence is a cross-domain tendency that is specific to autism. It is argued that the results from previous studies that have found a difference between groups on the homograph and homophone tasks (Frith & Snowling, 1983; Jolliffe & Baron-Cohen, 1999; Snowling & Frith, 1986) may be more reflective of verbal ability level rather than problems in coherence.

An obvious advantage of the WCC theory, given the uneven cognitive profile in autism, is that it can account for skills as well as failures, and the suggestion that superior performance is found on tasks where piecemeal processing conveys an advantage has received some empirical support. However, less clear is how a single cognitive mechanism can give rise to both 'low' and 'high' level WCC. One suggestion has been that in autism there is a 'narrow' spotlight of attention that enhances processing at particular locations (Townsend & Courchesne, 1994). Another proposal has been that right hemisphere attentional processes that process overall forms (Lamb, Robertson, Knight, 1990) may be compromised in autism, and thus constitute the locus of the 'low' level WCC mechanism.

Studies investigating the WCC theory have found two findings to be consistent. It has been shown that individuals with autism are able to respond to the global level of a hierarchical stimulus (Mottron & Belleville, 1993; Plaisted Swettenham & Rees, 1999). It has also been shown that individuals with autism show faster and more accurate responses to the local level (Mottron et al., 1993; Plaisted et al., 1999). It is suggested that WCC is more pervasive in low functioning individuals, while integration may be relatively spared in higher-functioning individuals (Brock, Brown, Boucher et al., 2002; Lopez & Leekam, 2003; Minshew, Meyer & Goldstein, 2002).

As well as accounting for perceptual abnormalities, the WCC theory has also been proposed to offer insights into specific communication problems of people with autism spectrum disorders (Noens & Van Berekelaer-Onnes, 2005), since a weaker drive for central coherence leads to problems in sense making and consequently in communication. Communication requires rapid processing of auditory (speech) and visual (non-verbal cues) stimuli (Fay & Schuler, 1980). Without coherence, one perceives a very disjointed picture with disconnected bits and pieces. An example comes from Van Dalen (1994) who reports on a high functioning autistic engineer who describes himself as 'seeing blind and hearing deaf.' Despite neither being the case, he is disadvantaged by the time he needs to process the stimuli step by step. Since natural communication occurs at a speedy pace, he frequently becomes confused by even the most essential information.

Many experimental studies highlight the inability of individuals with autism to use context. Happé (1993; 1994) carried out studies on figurative language in autism, and found an impairment in their understanding of, and their use, of appropriate mental state explanations for story characters' non-literal utterances such as lies, jokes and sarcasm. Although the participants with autism gave as many mental state explanations as the participants in the control groups, their responses were not context appropriate. Studies by Jolliffe and Baron-Cohen (1999; 2000) found that individuals with both high-functioning autism and Asperger syndrome failed to use context to interpret ambiguous sentences that were presented auditorally as well as when arranging sentences coherently on a visual task.

Noens & Van Berekelaer-Onnes (2005) have attempted to explain how WCC may also affect specific areas of language. Prizant (1983) predicted that children with autism use a Gestalt strategy in early language. Gestalt language can be explained in terms of memorised forms or whole units built from both linguistic processes and a combination of rules. Echolalia, pronoun reversal, neologisms and metaphorical remarks could all be generated this way. If individuals with autism have an inability to extract meaning for context as predicted by WCC, the only way to learn language may be to memorise complete chunks and reproduce them identically. This would cause problems with both literal association and unfamiliar words or those spoken in a context different to that in which they were learned (Noens & Van Berekelaer-Onnes, 2002; cited in Noens & Van Berekelaer-Onnes, 2005). Autistic children have been shown to be significantly poorer than normal children at distinguishing inappropriate utterances, suggesting that they have poorer knowledge about the social constraints of appropriate communication (Surian, Baron-Cohen & Van de Lely, 1996). They have also been shown to be overly literal and to talk at great length on socially inappropriate and obscure topics (Ozonoff & Muller, 1996). The tendency to take things literally is also demonstrated in pedantic, over-exact comprehension and production (Happé & Frith, 1996). A reliance on memory forms is evidenced in concept formation as shown from a report by Grandin (1995) whose concept of 'cat' consists of a collection of all the cats she has ever seen rather than that of a generalised cat.

There are alternative proposals for the mechanism that underpins enhanced local processing. The generalisation hypothesis (Plaisted 2001) proposes that abnormal perceptual processing in autism enhances the salience of individual stimulus features, and allows greater acuity in their representation without compromising global configurations. According to this theory, individuals with autism process features unique to a situation or stimuli relatively well, and features held in common with other stimuli rather poorly. This leads to two predictions. First, individuals with autism should show superior performance on a difficult discrimination task; for example, one where stimuli to be discriminated hold many elements in common and each possesses very few unique elements. Second, individuals with autism should show inferior performance on a task that requires categorization of two sets of stimuli (Plaisted, Saksida, Alcantara et al., 2003).

Support for the first prediction was demonstrated in a perceptual learning task (Plaisted, O'Riordan & Baron-Cohen, 1998b). In these tasks, two very similar stimuli, which at first appear indistinguishable, become distinguishable following a period of exposure. If individuals with autism process the unique elements of stimuli well and the common elements poorly, they should not require exposure to the stimuli in order to discriminate them. The findings from the study supported this, and showed that participants with autism performed as well on discrimination tasks involving novel stimuli as on those with discrimination conditions involving pre-exposed stimuli.

Support for the second prediction, that individuals with autism should show a deficit in categorisation, was found using a prototype abstraction task (Plaisted, O'Riordan, Aitken & Killcross; submitted; cited in Hill & Frith, 2003). When typical adults are first trained to categorise two sets of exemplars, they are subsequently able to categorise the prototype of each set more accurately than other non-prototypical exemplars even though they have never experienced the prototypes before. Individuals with autism showed a deficit in category learning in the initial categorisation phase of a prototype experiment, and a reduced prototypes effect in comparison to normal subjects.

The generalisation hypothesis predicts that a reduction in the processing of common features will reduce the extent to which prior experiences influence new experiences, therefore resulting in increased difficulties in extracting the gist or meaning from a current situation. Also, the proposal that individuals with autism process unique features better than normal individuals can account for why individuals with autism often notice features that seem irrelevant to those without the disorder. Finally, the proposal that perception operates differently in autism to allow for finer registration of the available stimuli has important implications for concept formation and category structure in autism. Specifically, the idea that perception in autism enhances the discriminability of stimuli predicts that category boundaries will be sharper and category content much narrower in autism. If categories have sharper boundaries, then it is less likely that novel unusual exemplars will be recognised and encoded as part of an existing category. This is highlighted by the interests of children with autism which tend to be characterised by very specific exemplars, so that a child with autism might be fascinated by a certain make of car, but entirely uninterested in other makes (Hill & Frith, 2003).

Another influential theory that emphasises the importance of low-level sensory information is the enhanced perceptual functioning theory (EPF) (Mottron & Burack, 2001). According to this theory, low level modules involved in the detection, discrimination and categorisation of perceptual stimuli are enhanced in autism. According to the EPF theory, pairs of systems compete in order to obtain a certain effect or to fulfil a certain function. Within each pair, one is linked to low level processing and the other linked to higher order processes. Evidence for a bias towards low level processing in autism includes local versus global processing in a visual hierarchical task (Plaisted, Swettenham & Rees, 1999), local versus global featuring in graphic construction (Mottron, Belleville & Ménard, 1999) and pitch (local) versus contour (global) in a musical task (Mottron, Peretz & Ménard, 2000). Whilst the WCC, EPF and RG theories differ slightly in emphasis, all share the assumption that individuals with autism have enhanced low-level perception and comparatively weaker global processing. This means that they provide an important theoretical context within which to consider findings from experiments into colour processing in autism.

Autism Spectrum Disorder and Colour Perception

Although there is a large body of research into visual perception in autism, no studies have specifically investigated colour perception. This is surprising given that autistic children's idiosyncratic responses to colours are widely described in the clinical literature. Unusual behavioural responses described include, for example, refusing to use a blue towel or drink out of any cup that is not green. Most of what is known about these phenomena comes from self or parental reports. For example, an adult with autism has written about how, as a child, he had been unable to look at the yellow bike he had been given for Christmas because of its colour. His parents attempted to remediate the situation by painting the bike red, but this resulted in an orange colour that looked to the child as though it was on fire (White & White, 1987). Donna Williams, a high functioning woman with autism, has written about how different coloured light bulbs can be used to influence her mood as well as the degree of comfort and accuracy with which she could see things. She has said "the red had me alert and aware and I started to look for things to do within the room instead of staring hypnotically at the mirror or wallpaper" (Williams 1999, p140). The Light and Sound Therapy Centre in London uses light therapy, and claims that this leads to improvements in physical and emotional functioning as well as in intellectual capacity in children with autism (Howlin, 1996). It has been claimed that light therapy is successful in remediating hypersensitivity to bright lights as well as difficulties with attention span and focusing. However, assessment of these claims has primarily been made through parental reports.

Visual processing abnormalities commonly reported in autism include sensitivities to illumination and colours (Myles et al., 2000; Attwood, 1994). Other phenomena include the experience of visual distortions which may, for example, alter the perceived dimensions of rooms (White & White, 1987; Attwood, 1994). These visual processing abnormalities can often be difficult for others to understand, and yet they can have a profound impact on functioning, particularly within education settings. Visual distortions can result in difficulties writing on printed lined paper and maintaining appropriate spacing between letters and words (Myles et al., 2000).

Colour overlays and tinted lenses have also been proposed to be of therapeutic benefit to individuals with autism. This is because autism and Meares-Irlen syndrome are believed to co-occur in some individuals with autism (Irlen, 1991; Williams, 1999; Wilkins, 2003). The term Meares-Irlen syndrome (also known as scotopic sensitivity syndrome or Irlen syndrome) describes 'perceptual stress' whereby different components of light (such as colour and source) are thought to lead to perceptual distortions when reading and/or viewing the environment (Irlen, 1991; Williams, 1999). For example, Irlen (1994) has proposed that, in the case of autism and Meares Irlen syndrome, perception becomes extremely fragmentary resulting in a range of negative outcomes. Individuals with this syndrome report that the perceptual distortions they experience when they read are reduced when the text is illuminated by light of a particular optimal colour (Evans, Wilkins, Busby et al., 1996; Wilkins, Jeanes, Pumfrey et al., 1996). Eye strain and headaches are reduced when spectacles tinted with this colour are worn (Wilkins et al., 1996).

Colour overlays are transparent coloured plastic sheets that are placed over texts without interfering with their clarity. They have been shown to eliminate symptoms of visual stress and reportedly increase reading speed (Jeanes, Busby, Martin et al., 1997; Irlen, 1991), as well as having positive effects on reading comprehension, other aspects of visual processing and attitude to school, in children with Meares-Irlen syndrome (Croyle, 1998; Jeanes et al., 1997; Robinson & Foreman, 1999). There is some evidence that colour overlays are of benefit to a substantial number of individuals, and Wilkins (2003) estimates that 25% of the population will read more than 5% faster when using a colour overlay. There are no studies into the effects of colour overlays in autism, although Irlen (1991) has proposed that they may be of benefit to a significant proportion of individuals diagnosed with this disorder. Coloured overlays have been found to provide therapeutic benefit for epilepsy sufferers (Wilkins, 1995) and by adulthood, one third of all individuals with autism will have had at least two epileptic seizures (Olsson, Steffenburg & Gilberg, 1988). Greater benefits have also been reported in sufferers of migraine (Maclachlan, Yale & Wilkins, 1993), photosensitive epilepsy (Wilkins, 1995), head injury (Padula, Argyris & Ray, 1994) and dyslexia (Evans, 2001).

In summary, experimental studies of colour processing in autism have not been carried out to date, although much anecdotal evidence suggests that these individuals frequently respond idiosyncratically to particular colours. Further, there are reports suggesting that the use of lights, colour overlays and tinted lenses can be of significant therapeutic benefit for some individuals with autism.

Of relevance, when considering research into colour processing in autism, is recent work showing that magnocellular and parvocellular systems function differently in autism in comparison to typical development (Boeschoten, Kemner, Kenemans et al., 2004; cited in Milne, Swettenham & Campbell 2005; Deruelle, Rondan, Gepner et al., 2004; Milne, Swettenham & Campbell, 2005). These systems have been implicated in enhanced perception and deficits in global processing as well as in colour perception. In primates, visual information from the retina projects to the primary visual cortex (V1) by way of the independent but linked magnocellular pathway and parvocellular pathways. The parvocellular pathway is most sensitive to high spatial frequencies and stationary or slowly moving targets, has a low temporal resolution and processes information used for wavelength and form discrimination. Conversely, the magnocellular pathway contains cells which are sensitive to low spatial frequency information like moving and flickering stimuli. It has a high temporal resolution and processes motion, spatial and depth information (Livingstone, Rosen, Drislane et al., 1991).

The magnocellular system is commonly regarded as being colour-blind and primarily involved in the perception of motion (Schillier & Logothetis, 1990), whereas the parvocellular system mediates colour vision. However, it has been questioned as to whether the parvocellular pathway is the only way that colours can be discriminated in human colour vision. The parvocellular pathway is assumed to control conscious colour perception, yet evidence from two patients with cerebral achromatopsia, who lack conscious colour perception, shows that they are still able to use colour information. Results from a forced-choice colour- and luminance- discrimination task showed clear evidence of unconscious colour processing in these patients. These findings support the fact that discrimination may be mediated by neural systems which respond to fast flicker and are spectrally non-opponent such as the magnocellular system, or a system known as the koniocellular (K) system (Troscianko, Davidoff, Humphrey et al., 1996). The koniocellular system is known to send projections to the primary visual cortex, although the functional characteristics of this system are as yet unknown (Casagrande, 1994).

The global aspect of a stimulus is represented by low spatial frequency information, and it is thought that the magnocellular visual pathway processes this. It has been shown that by attenuating the magnocellular pathway, the global precedence effect is also attenuated (Michimata, Okubo & Mugishima, 1999). Plaisted et al., (1999) have suggested that the local bias in children with autism seen on the Navon task could be attributable to high levels of activity in the high spatial frequency channels (parvocells). However, Milne, Swettenham, Hansen et al., (2002) have shown that, in a task in which children were required to detect the direction of moving dots in a random dot kinematogram, those with autism showed higher motion coherence thresholds which points to low levels of activity in the low spatial frequency channels (magnocells). This replicated the findings of Spencer, O'Brian, Riggs et al., (2000) who also found high motion coherence thresholds using a random kinematogram in children with autism compared to verbal mental age typically developing children.

It is of interest that low spatial frequencies have been suggested to mediate perceptual global bias, as seen in hierarchical stimuli such as Navon-type figures (Badcock, Whitworth, Badcock et al., 1990; Hughs, Nozawa, & Kitterle, 1996; Navon, 1977). Several studies have shown abnormal perception of these figures in autism (Mottron & Belleville, 1992; Plaisted, Swettenham & Rees, 1999), and Milne, Swettenham, Cambell et al., (2004) extended these findings by showing that the children with autism with a local processing bias had high motion coherence thresholds (reduced motion sensitivity), whereas those children with autism with a global processing bias had normal motion coherence thresholds. Milne, Swettenham & Campbell (2005) suggest that if coherent motion detection is indicative of magnocellular integrity, the reduced global bias and enhanced local bias seen in autism might be one outcome of abnormal magnocellular processing.

Although the magnocellular pathway is known to inhibit the parvocellular pathway (Singer and Bedworth, 1973), it remains unclear whether a local processing bias occurs because of impairment and degradation of low spatial frequency processing, or because an impaired magnocellular pathway exerts less inhibition on the parvocellular system. Thus, if the magnocellular pathway controlling global processing is damaged in autism, enhanced local processing may reflect an intact but uninhibited parvocellular pathway. If damage to the magnocellular pathway results in higher levels of activity in the parvocellular pathway where colour is processed, overactivity might result in some of the powerful and aversive experiences anecdotally reported.

Of relevance to the question of brain abnormalities that give rise to unusual visual-perceptual experiences are findings from studies into dyslexia. Firstly, individuals with dyslexia have been found to show impaired function of the visual magnocellular pathway (Iovino, Fletcher, Breitmeyer et al., 1998; Wilkins 2003) with high motion coherence thresholds, similar to those found in autism (Milne et al. 2002, Spencer et al., 2002). Interestingly, it has been found that the sensitivity of most dyslexics to flickering stimuli and low contrast gratings and motion stimuli is lower than in individuals without dyslexia (Cornelissen, Richardson, Mason et al., 1995). On the other hand, the perception of colour and finely detailed stimuli have turned out to be no different from, and in some cases better than that in individuals without dyslexia (Stein & Talcott, 1999). It remains unclear whether this is the same for individuals with autism.

Research has shown that some individuals with dyslexia benefit from the use of colour overlays. This has also been found to be the case for migraine sufferers who also show magnocellular abnormalities (Wilkins, 2003). However, a major problem with a magnocellular deficit explanation for the visual disturbance seen in individuals who benefit from the use of coloured overlays is how it can account for the wide range of self-selected colours used by these individuals (Evans, 2001). It also appears to be the case that a significant proportion of individuals without dyslexia or other disorders associated with magnocellular abnormalities benefit from the use of colour filters (Kriss, 2002; Wilkins & Grounds: in preparation), and magnocellular function does not appear to be abnormal in Meares-Irlen syndrome (Evans et al., 1996; Simmers, Bex, Smith et al., 2001).

An alternative explanation for the beneficial effects of colour filters is that it mediates cortical hyperexcitability. This theory is given support by the fact that coloured filters have been found to benefit individuals with a wide range of central nervous disorders where the cortex is presumed to be hyperexcitable, such as photosensitive epilepsy (Wilkins & Lewis, 1999), migraine (Evans et al., 2002; Wilkins, Patel, Adjamian et al, 2002), and head injury (Jackowski, Sturr, Taub et al., 1996). Wilkins (2003) has proposed that visual distortions occur as a result of a spread of activation within the cortex that causes cells to fire inappropriately. Self-selected colour filters redistribute excitation in such a way that over-excitation of locally hyperexcitable regions is avoided. This proposal has been given recent support by findings from fMRI studies showing hyperexcitability in the visual cortex of migraine sufferers (Huang, Cooper, Satana et al., 2003; Huang, Wilkins & Cao, 2004). Further evidence is provided as topographic encoding of colour has been found in areas of the cortex such as V2 (Xiao, Wand & Felleman, 2003), and various spectral sensitivities of neurons in V3 and V5 have also been reported (Zeki, 1980; Zeki, 1983).

Whilst neurological studies into autism have been carried out, there is currently no clear consensus on the neural basis of this disorder. Findings from functional imaging studies have shown that several cortical and subcortical regions are implicated (Filipek, Richelme, Kennedy et al, 1999; Rumsey & Ernst, 2000), and structural imaging studies suggest that abnormalities in white matter are at least as extensive as those in grey matter (Filipek, 1992). Studies comparing the brains of those with autism to normal controls have revealed differences in the temporal parietal cortex, the intraparietal cortex, the limbic system, the cerebella and the prefrontal regions (Belmonte & Yurgelum-Todd, 2003; Brambilla, Hardan, Ucelli di Nemi et al., 2003; Aylward, Minshew, Field et al., 2002; Bailey, Le Couteur, Gottesman et al., 1995; Carper, Moses, Tigue et al., 2002; Courchesne, 2002; Lainhart, Piven, Wzorek et al., 1997). It may also be the case that abnormalities in the brains of adults with autism reflect environmental effects. For example, abnormal social interactions may compound initial brain abnormalities resulting in deviant patterns of connectivity within and between regions (Johnson, 2000). Support for this suggestion comes from findings showing deviant cortical activation patterns in autism in comparison to controls, even in situations where behavioural measures do not distinguish the two groups (Mill, 2000). Rubenstien and Merzenich (2003) and Belmonte, Cook, Anderson et al., (2004) have proposed that there may be an imbalance between excitation and inhibition in key neural systems including the cortex in autism (Rubenstien & Merzenich, 2003; Belmonte et al., 2004). In fact, several candidate genes have been shown to control the early synaptic maturation of specific neuronal sub-populations controlling the balance between excitation and inhibition in the developing cortex of individuals with autism (Polleux & Lauder, 2004).

Gustafsson (1997) has proposed a neural circuit theory of autism. This model proposes that excessive inhibition will result in the formation of inadequate cortical feature maps. Inadequate feature maps affect memory functions and higher cognitive functions by inhibiting the extraction of feature information from sensory input or cortical areas. Some feature maps may not have developed, others may have been delayed or have narrow neural column width which may contribute to the uneven pattern of cognitive abilities seen in individuals with autism (Frith, 1989).

One neuropathological study (Casonava, Buxhoeveden & Switala, 2002; Casonva, Buxhoeveden, Switala et al., 2002) found a reduction in the size of cortical minicolumns and an increase in cell dispersion within minicolumns in postmortem autistic brains. It was speculated that an increase in the total number of minicolumns would lead to over-connected and insufficiently inhibited neural networks, with consequent hyper-arousal and impaired selection. In a recent study, more cerebral white matter was found in the autistic brain than in the typically developing brain. Cortical regions failed to differ, but showed a trend towards being smaller in the autistic sample relative to total brain size (Herbert, Ziegler, Deutsch et al., 2003). This dissociation between cortex and white matter may alter the relationship between cortical structures and axonal connections, and consequently may compromise the optimality of connectivity in the brains of people with autism (Zhang & Sejnowski, 2000). This could result in deficits in complex information processing (Minshew, Luna, Sweeney et al., 1999) and in impaired temporal binding or neural integration (Nunez, 2000; Brock et al., 2002).

Herbert al., 2003 and Just, Cherkassky, Keller et al., 2004, have proposed an underconnectivity model of autism. According to this model, there may be preservation and/or enhancement of the functions of individual cortical centres, but integration of information among cortical centres is impaired. This theory was proposed to explain the preservation of skills requiring less co-ordination among cortical centres (shown in visual search tasks), as well as poorer performance on tasks (sentence and story comprehension) which require higher levels of integration.

As previously suggested, no systematic studies into colour processing in autism have been carried out. However, such studies are of interest both clinically and theoretically. Therapeutic interventions involving exposure to coloured lights and filters appear to be of benefit to individuals with autism (Howlin, 1996; Irlen, 1991) although little is understood about the specific mechanisms involved or the extent to which these could benefit many more individuals with autism. Cases of "colour phobia" are frequently reported anecdotally, but little is known about the behavioural impact of these difficulties or of the individuals who display them. In the latter part of this chapter, two hypotheses, the magnocellular deficit account and the cortical excitability hypothesis, have been put forward to explain the beneficial effects of colour overlays in children with autism. They have also been discussed in terms of how they might account for other characteristics in autism such a bias towards local processing, their role in colour processing and how they sit with neurological theories of autism. Theories of enhanced perceptual or local processing in autism also provide a useful theoretical framework for research into visual processing, and the studies to be presented in this thesis will be discussed within the context provided by these. An issue that is of current theoretical interest relates to the role of perception and language in colour processing. As outlined in this chapter, children with autism typically possess an uneven profile of abilities, with good or enhanced perceptual processing and relatively poor language skills. The study of colour perception, categorisation and memory in these children may then provide a significant contribution to this debate.

Structure of the Thesis

This thesis will investigate colour processing in autism and controls using a range of measures. In chapter two the effect of colour overlays on single word reading will be investigated. Chapter three will extend the findings from chapter two by investigating other aspects of cognition that improve when a colour overlay is used. The experiments will test reading comprehension and visual discrimination with and without colour overlays. Chapters four and five will investigate the role of perception and language on colour processing ability. Therefore colour naming, comprehension, discrimination and categorisation will be investigated in chapter four. Chapter five will attempt to isolate the effects of colour names and perceptual information in memory in three paired-learning experiments. Chapter six will provide a detailed case study of a child with Asperger's syndrome and colour obsessions. The results from all the studies will be discussed in chapter seven.

All the children who participated in the studies throughout the research were boys. Ethical clearance was obtained from Goldsmiths College Psychology Department ethical committee. Permission was sought from both schools and parents of the individual children. Only those children whose parents gave written consent were allowed to participate in the tasks, and their parents were offered both the group results and the results for individual children. Testing for each of the studies was carried out in a quiet classroom at the children's schools. Experiments presented in chapters four and five took place in a classroom with only a day light bulb next to the computer as artificial light. Complete darkness could not be obtained as it would have caused the children undue stress.

CHAPTER TWO

THE USE OF COLOUR OVERLAYS ON READING ABILITY IN CHILDREN WITH AUTISM*

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Summary: Abnormalities of colour perception in children with autistic spectrum disorders have been widely reported anecdotally. However, there is little empirical data linking difficulties in colour perception with academic achievement, for example reading ability. The Wilkins Rate of Reading Test (Wilkins, Jeanes, Pumfrey et al., 1996) was administered with and without *Intuitive Coloured Overlays* to nineteen children with autistic spectrum disorders, and to the same number of controls individually matched for age and intelligence. The findings from the study showed that fifteen out of nineteen (79%) children with autism showed an improvement of at least 5% in reading speed when using a coloured overlay. In contrast, only three out of nineteen (16%) control group children showed such an improvement. The findings suggest that coloured overlays may provide a useful support for reading for children with autism.

INTRODUCTION

In the introductory chapter, anecdotal reports of abnormalities in visual processing in autism were outlined. Therapeutic approaches, based on the assumption that visual processing abnormalities in autism are disruptive to everyday functioning were described and it was noted that, whilst investigations into these approaches with individuals from other diagnostic groups with visual processing abnormalities have been carried out, such effects have not been systematically investigated in autism.

The study described in this chapter will therefore be the first to evaluate one such therapeutic intervention.

Colour overlays are transparent coloured plastic sheets that can be placed over printed texts without interfering with their clarity. An important aspect of this intervention is that participants themselves select the overlay that they perceive best improves the clarity of the printed text. The chosen overlay can be any one from the two sets of identical ten (nine coloured and one grey) provided in the Intuitive Overlays Selection pack (Wilkins 1994). Participants can use a single overlay or can select double overlays that provide a stronger colour. Research using this test has been carried out with children in mainstream schools, and has shown that in 7 – 11 year old children, 5% read more than 25% faster, and 20% read more than 5% faster when using a coloured overlay (Wilkins, Lewis, Smith et al., 2001). In addition to improvement in reading speed with coloured overlays, corresponding improvements in reading accuracy have been found (Wilkins et al., 1996). Although such extensive studies have yet to be carried out with adults, researchers working in this area have suggested that the rate of improvement in adults might be similar to that found in children (Evans & Joseph, 2002).

Although the Intuitive Overlays allow freedom of selection to participants, colour choice tends to be consistent within individuals over testing sessions. For example, in a study by Wilkins et al., (2001), 47% of a sample of children chose the same overlay on two separate testing sessions three days apart, and of the remaining sample, 21% chose an overlay of a similar colour (neighbouring chromaticity). It was also noted that the children who chose exactly the same colour on both occasions showed the greatest improvement in reading speed. In another study, 368 children were given a random, rather than self-selected, overlay for use in the classroom for a few months before being given their chosen overlay. The findings showed that children who by chance were given their chosen overlay or one that was of similar colour, elected to use the overlays for a longer period than the children who had been given random overlays (Wilkins et al., 2001).

Studies carried out with typically developing children have shown that the benefit of overlays is not simply due to placebo effects. One such research design, adopted in two separate studies (Wilkins & Lewis, 1999; Bouldoukian, Wilkins & Evans, 2002) compared reading rates with no overlay, with a chosen overlay, with a grey overlay, and a grey overlay that was identical except that it was labelled, "scientific prototype". Children were told that the prototype was new and combined all colours and that they would be the first to use it. The findings from the study showed that improvements in reading were only seen in those who had chosen a coloured overlay and no placebo effects were found. In a similar vein, Jeanes et al., (1997) tested the rate of reading in five different conditions. These were (1) without an overlay, (2) with a clear (transparent) overlay, (3) with the grey overlay from the Intuitive overlays, (4) with two coloured overlays from the same set, (5) with one of the chosen colour and one of a colour opposite (complementary) to that chosen. Again, the rate of reading was only superior in the chosen colour overlay condition.

It would seem logical that the proportion of individuals who benefit from overlays will be over-represented in populations of people with reading difficulties such as dyslexia.

This was originally proposed by Irlen (1991). Dyslexia is evident when accurate and fluent word reading and/or spelling develops incompletely or with great difficulty (British Psychological Society, 1999) and it is the most common of the learning difficulties. Some of the subtle visual deficits seen in individuals with dyslexia are similar to those found in people with Meares-Irlen syndrome (Evans, 2001). However, recent findings have shown that individuals with dyslexia benefit from overlays only slightly more frequently than the rest of the population (Kriss, 2002). Many of the symptoms of Meares-Irlen syndrome are not specific to this disorder. For example, children with attention deficit/hyperactivity disorder (ADD/ADHD) share symptoms with both Meares-Irlen syndrome and dyslexia, and these include difficulties in tracking words and lines when reading, and poor concentration (Stone, 2002). Thus whilst overlay use has not yet been shown to benefit any one specific group, children with reading difficulties are more likely than others to report visual perceptual distortions (Evans, 2001; Wilkins, 2003). As coloured overlay use appears to be one way of removing these distortions, they may be especially beneficial to these children with reading difficulties.

Donna Williams (1999) an able adult with autism was one of the first individuals with this disorder to describe therapeutic benefits from using coloured filters. She describes hyper-acute vision that results in a tendency to focus on minute details, and reports that tinted lenses enable her to view the world clearly and holistically. She has proposed that many individuals with autism would benefit from using coloured lenses.

Although the mechanisms of benefit are currently uncertain, Wilkins (2003) has presented evidence that peripheral mechanisms in the brain are insufficient to explain the phenomenon, and that the mechanisms are central and cortical in origin. However, clues to the cortical abnormalities that can be remediated by overlays come from several sources. For example, children who benefit from the use of colour overlays are twice as likely to come from families with a history of migraine as those who do not benefit (Maclachlan, Yale & Wilkins, 1993), and the cortex is believed to be hyperexcitable in migraine (Aurora & Welch, 1998; Huang et al., 2003). Visual stimuli that provoke photophobia, a negative reaction to bright lights, are similar to those responsible for causing seizures in patients with photosensitive epilepsy (Wilkins, 1995). Susceptibility to visual distortions can occur in the normal population, although migraine sufferers appear to be particularly sensitive to these (Marcus & Soso, 1989; Chronicle & Wilkins, 1991; Chronicle, Wilkins & Coleston, 1995). Wilkins (2003) proposes that visual distortions occur when a spread of activation within the cortex causes cells to fire inappropriately. He further proposes that this cortical hyperexcitability is similar to that seen in epilepsy, though less extreme. In photosensitive epilepsy, hyperexcitability can be diffuse, though not necessarily uniform. Importantly, it sometimes appears to involve only few cortical orientation columns (Wilkins, 1995). Xiao, Wand, & Felleman (2003) have shown that in visual area V2, colour sensitive cells are distributed topographically according to chromaticity. Wilkins (2003) has proposed that appropriately coloured filters change the distribution of firing within the cortex so as to reduce the excitation in hyperexcitable regions. Findings from fMRI studies investigating the hyperexcitability that occurs in migraine (Huang et al., 2003; Huang, Wilkins & Cao, 2004) have provided preliminary support for this suggestion. The cortical hyperexcitability hypothesis predicts that coloured filters will benefit individuals with any of a number of central nervous system disorders in which the visual cortex is hyperexcitable. In support of this are studies showing that coloured glasses are beneficial in photosensitive epilepsy (Wilkins & Lewis, 1999), migraine (Evans et al., 2002; Wilkins et al., 2002) and head injury (Jackowski, Sturr, Taub et al., 1996).

Individuals with autism are liable to epileptic seizures (Rutter, 1970; Ornitz, 1973; Deykin & MacMahon, 1979; Wing & Gould, 1979; Steffenburg & Gillberg, 1986; Bryson, Clark, & Smith, 1988; Tanoune, Oda & Kawastima, 1988; Cialdella & Mamelle, 1989), and for one third of this population epileptic seizures are experienced from early adulthood (Gillberg, 1991). In addition, perceptual distortions are also reported fairly frequently (Irlen, 1991; Williams, 1999). It is therefore plausible to suggest that cortical hyperexcitability is characteristic of at least some individuals with autism. If this is the case and coloured filters do reduce cortical hyperexcitability, therapeutic benefits may well be found in this group. This will be tested in the following experiment.

Although the majority of children with autism also have varying degrees of intellectual impairment, many learn to read (Locker & Rutter, 1969; Cobrinik, 1974; Bartak & Rutter, 1975). It is therefore possible to investigate changes in reading with and without coloured overlays in these individuals. The present study will test the hypothesis that a greater proportion of children with autism will read faster and more accurately with overlays than controls matched for verbal IQ and chronological age.

EXPERIMENT ONE: TESTING RATE OF READING

Participants

Nineteen children with autism participated in the experiment. These children were aged between 8 years and 4 months and 15 years and 1 month (mean 11 years and 10 months). All children attended schools for which a formal diagnosis of autism was the criterion for entry. Their scores on the British Picture Vocabulary Scale (BPVS) (Dunn, Dunn, Whetton et al., 1997) ranged between 47 and 87 (mean 64.3). Control participants were typically developing children recruited from mainstream schools, and children with moderate learning difficulties recruited from special needs schools. These children were matched to the children with autism on an individual basis for chronological age, gender and verbal IQ as measured by the British Picture Vocabulary Scales (Dunn et al., 1997).

All children also completed two colour abnormality tests: the Ishihara Test (Ishihara, 1970) and the City University Colour Vision Test (3rd edition; Fletcher 1998). The Ishihara Test provides a sensitive measure of the red/green confusion associated with protanomly and deuteronomaly. The City University Colour Vision Test (3rd edition; Fletcher, 1998) involves discrimination of shades of colour, and includes a measure for tritan defects which can cause difficulty with the colour blue and some other colours. These data, together with age and verbal IQ data, is shown in table 2.1 below.

Table 2.1: Age, verbal IQ and colour test data for children with autism and controls.

Group	Age		BPVS		City University Test		Ishihara	
	Mean	sd	Mean	sd	Mean	sd	Mean	sd
Autism (N=19)	11.10	(2.23)	64.32	(10.91)	15.9	(0.33)	36.7	(1.04)
Controls (N=19)	11.9	(1.95)	68.36	(12.75)	15.9	(0.34)	35.7	(1.21)

Optimal score on City University colour test=16; Optimal score on Ishihara=38

Materials

The *Intuitive Overlays* are sheets of coloured plastic sheet suitable for placing over a page of text so as to colour the text beneath without interfering with its clarity. They sample chromaticity systematically and efficiently (Wilkins 1994). They are supplied in a teacher's pack and include two A5 size overlays of each of the following colours: rose, orange, yellow, lime green, mint green, aqua, blue, purple, pink and grey.

The Rate of Reading Test is a passage consisting of 20 lines, each with the same 15 common words in a different random order. The words are of high frequency and therefore familiar to poor readers. The random word order ensures that no word can be guessed from the context but each must be seen to be read. Absence of meaning has the advantage that children are often unaware of the errors of omission and insertion of words. The passage is read out aloud for a minute and the score is the number of words read correctly in the appropriate order (Wilkins et al., 1996). The published test exists in two versions that differ only as regards typeface, size and spacing. The larger text (14pt Geneva) was used.

Procedure

A test page consisting of two A4 pages with two identical passages of the Rate of Reading text side by side was positioned in front of the child at a reading distance of 0.4m. The page was positioned so that no light sources were directly reflected from the surface of the overlays. Children were asked to read the passage for 30 seconds and told that it was a practice run and that the passage did not make sense. Then, while the children were still looking at the passage, they were asked the following visual stress questions - "Do the letters stay still or do they move?"; "Are they clear or are they blurred (fuzzy, difficult to see)?"; "Are the words too close together or far enough apart?"; "Is the page too bright, not bright enough, or just about right"; "Does the page hurt your eyes to look at or is it ok?". The questions reveal symptoms that are generally slightly greater in those who show improvements in reading speed with overlays (Wilkins et al., 2001). All of the participants in the study were verbal, and gave ready responses to the questions asked. No children asked for clarification on any of the questions asked. A score of 1 was given for each visual stress symptom expressed (these are underlined), whilst others responses scored 0.

The colour overlays were assembled in a pile in the following order: rose, lime-green, blue, pink, yellow, aqua, purple, orange, mint-green. The order was designed to avoid complementary colours being placed next to each other. The top overlay (rose) was placed on the left hand side of the test page, covering one of the two passages of text, matt side uppermost. Children were asked which side was the clearest and most comfortable to see If the white side (passage without overlay) was best, then the overlay was removed and replaced with the next overlay from the pile. If the coloured overlay was selected as the best, then the overlay was turned over to see whether the matt side or the gloss side was preferred. The preferred side was then used for the remaining overlays.

When an overlay was judged to be preferable to the uncovered side, it was positioned with best side uppermost and another overlay was placed in the opposite side of the page so that both pages were now covered with overlays. The child was then again asked which side was the clearest and most comfortable. This process was continued each time leaving the best overlay in place and removing the poorer overlay, replacing it with the next from the pile. When two colours were deemed indistinguishable both colours were noted and one of the colours changed. The other colour was re-introduced at the end of the pile.

Finally, the researcher compared the chosen overlay to no overlay in order to ensure child's preferred overlay compared to no overlay to be sure of the best final selection. When the children had selected an overlay, researchers asked questions about visual stress again.

Stronger colours in the form of double overlays were next used to see if they made the text clearer than a single overlay. Stronger colours of the chosen hue were obtained by placing two overlays of the same or neighbouring chromaticity on top of each other to form a double overlay, as described in the *Intuitive Overlays* instruction booklet. The best single overlay was compared with the three associated double overlays and the optimal chosen by a process of elimination. If a double overlay was preferred, the questions concerning symptoms were repeated a third time.

RESULTS

Coloured overlays and rate of reading test

Three of the controls did not choose an overlay and preferred the text plain. These three children were not included in the analysis. Table 2.2 shows the means and standard deviations on the rate of reading with and without an overlay.

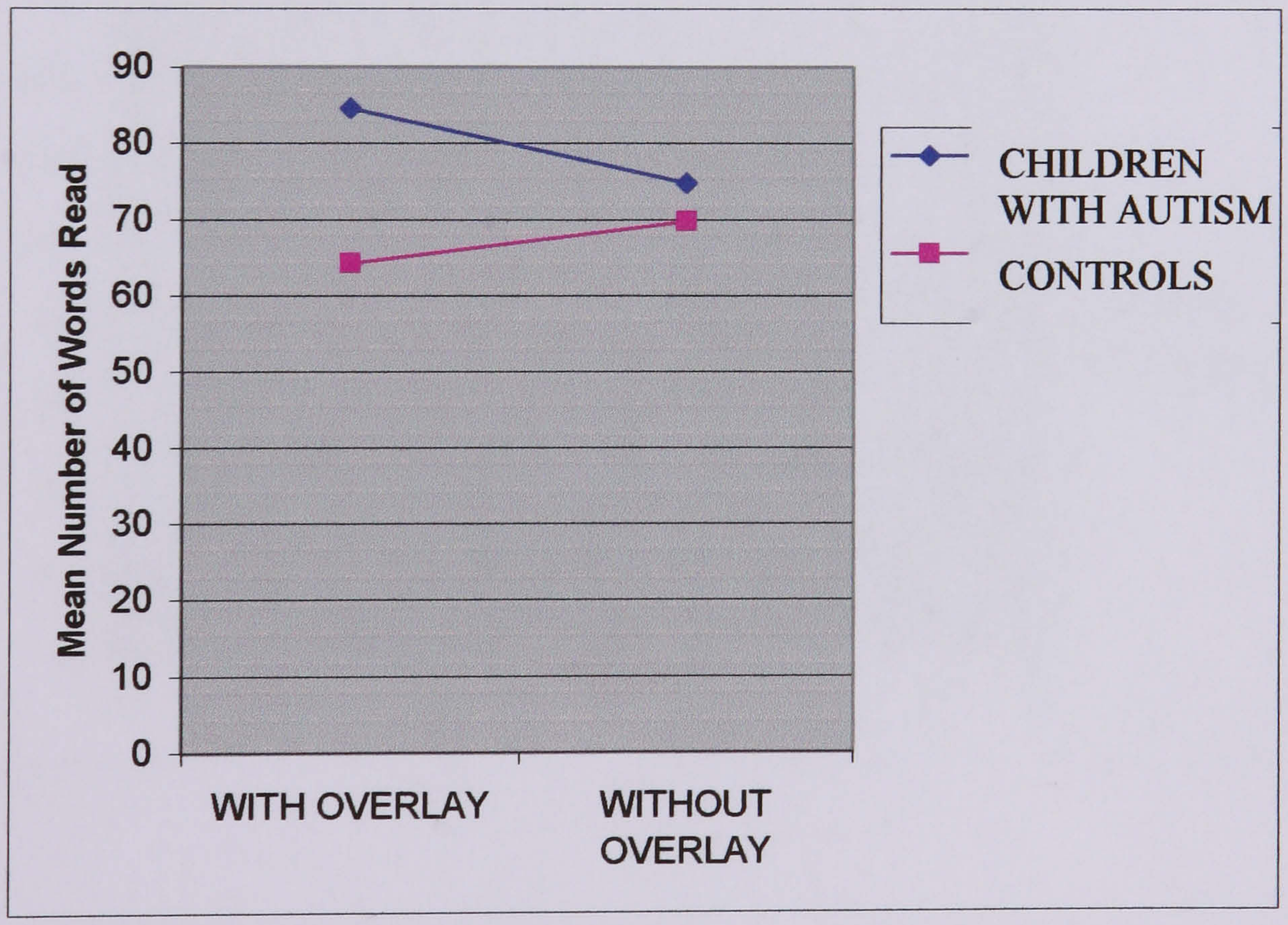
Table 2.2: Mean number of words read per minute with and without a colour overlay

Group	Number of words read with an overlay		Number of words read without overlay		Percentage Faster	
	Mean	sd	Mean	sd	Mean	sd
Autism (19)	84.63	26.84	74.75	27.34	16.31	18.42
Controls (16)	64.19	26.35	69.68	30.58	-4.92	12.38

Previous studies using the Intuitive Colour Overlays have set a 5% increase in reading speed as the criteria for significant effects (Wilkins, 2003). Therefore an initial analysis, using a 2*2 chi-square was carried out. This showed that significantly more children with autism read faster at the 5% level with the overlays, $\chi^2 = 12.60$; df=1, $p<.001$.

A 2*2 ANOVA was then carried out on the data. Group (autism/controls) was the between factor and condition (number of words read per minute with and without overlays) as the within group factor. The analysis showed no significant main effect of condition $F(1,33)=1.26$, n.s.) or group $F(1,33)=1.91$ n.s.). However there was a significant group x condition interaction ($F(1,33)=15.47$, $p<.05$). This is shown in figure 2.1 below.

Figure 2.1: Mean number of words read per minute with and without an overlay



This interaction was analysed using paired t-tests. These showed that children with autism read significantly more words per minute with than without colour overlays (t(18)=-3.28, p<.05). The difference was also significant for controls although here performance was poorer with overlays (t(15)=2.39, p<.05). No significant between group difference (autism/controls) was found when children read without colour overlays (t(33)=.52, n.s.), but children with autism read significantly faster than controls with colour overlays (t(33)=2.26, p<.05). As there was a high degree of variability in scores, particularly for the children with autism, individual data are shown in figures 2.2 & 2.3 below.

Figure 2.2: Words read per minute with and without colour overlays for children with autism

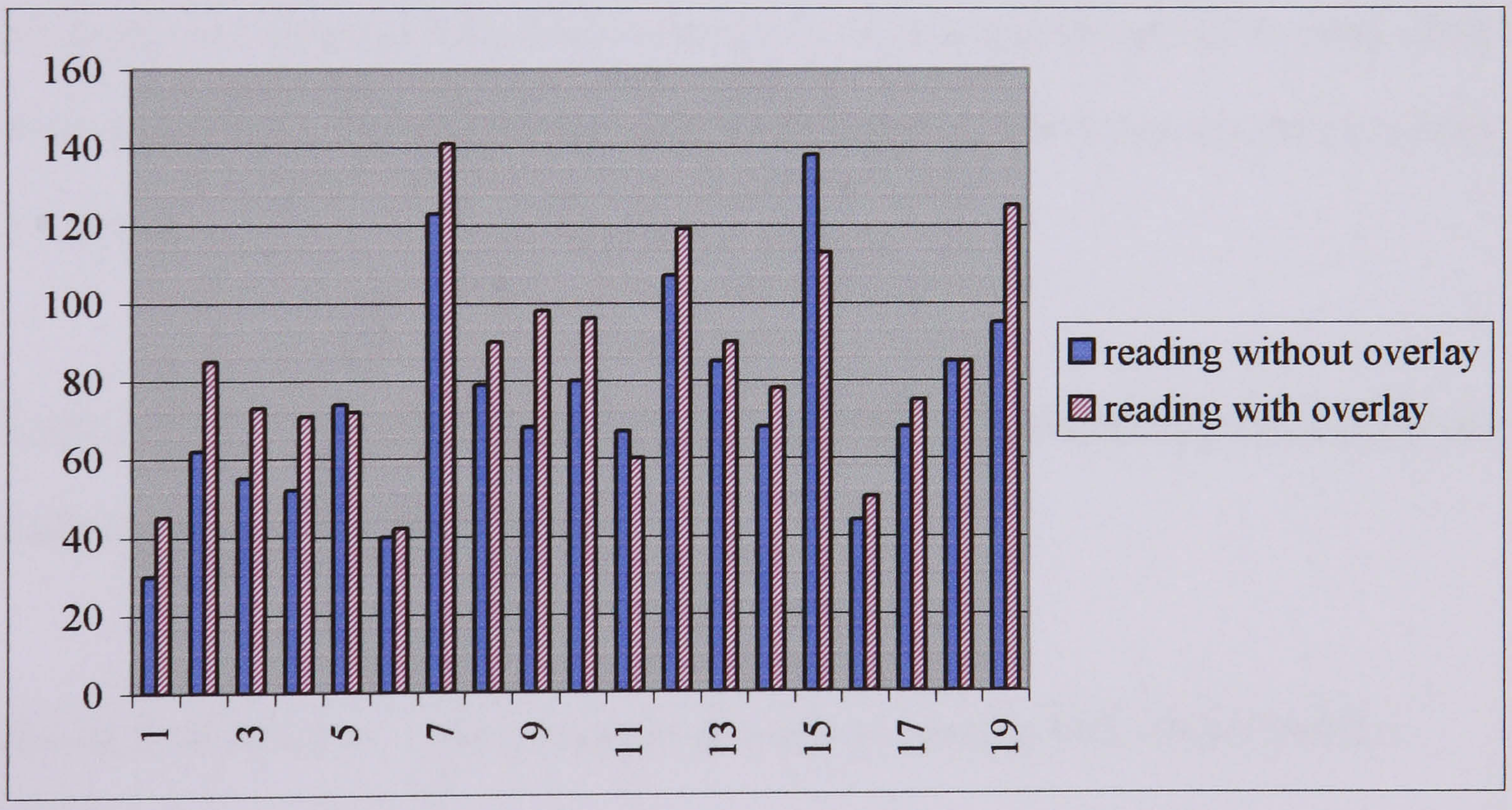
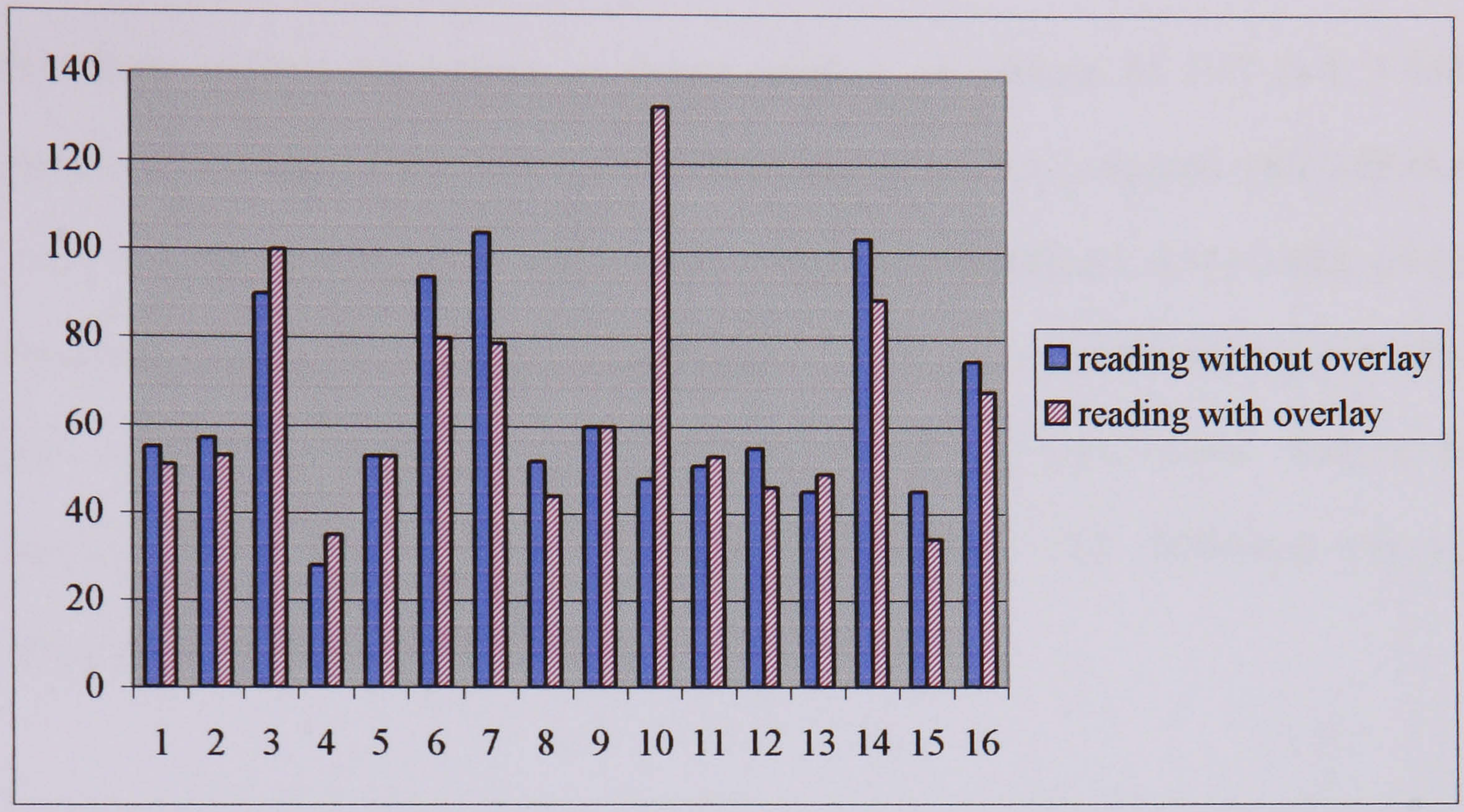


Figure 2.3: Words read per minute with and without colour overlays for control children.



Although the criteria for a significant increase in reading speed is set at 5%, many of the children improved reading speed at higher rates than this. These data are shown in table 2.3 below

Table 2.3: The percentage of improvement in reading in the group with autism and their controls with a colour overlay

Numbers of children showing improved reading with overlays	Percentage improvement reading with colour overlays				
	5-10%	11-20%	21-30%	31-40%	41-50%
Autism 15 (out of 19)	3 (16%)	6 (31%)	0	4 (21%)	2 (10%)
Controls 3 (out of 19)	1 (5%)	1 (5%)	1 (5%)	0	0

Visual stress

For those children who chose an colour overlay, an average of 1.17 (s.d. 1.043) symptoms of visual stress were reported without the overlay compared with 0.69 (s.d. 1.15) with the overlay. This difference is statistically significant, $t(34)=3.022$, $p<.05$. However, children who showed improvements in reading speed that were greater than 5% reported an average of 1.37 (s.d. 1.25) symptoms of visual stress without the overlay compared to 1.05 (s.d. 1.43) with an overlay. This difference was not statistically significant, $t(18)=1.18$, n.s.

Correlations carried out on the data showed that, for the autism group, there was no correlation between BPVS scores and the number of words read per minute with an overlay ($r=-.33$, n.s.) or without an overlay ($r=-.29$, n.s.). There was a correlation between age and number of words read with an overlay ($r=.55$, $p<.05$) and without ($r=.50$, $p<.05$). For controls, there was no correlation between BPVS scores and number of words read per minute with an overlay ($r=.28$, n.s.) and without ($r=.24$, n.s.). There was no correlation between age and the number of words read with an overlay ($r=.32$, n.s.) and without an overlay ($r=.41$, n.s.).

There was no marked overall preference for any specific colours within either group. The distribution of colour overlays chosen by individual children is included in Appendix (i).

DISCUSSION

The findings from this study are the first to investigate the influence of coloured overlays on reading in children with autism. The results from the study showed that when a 5% increase in reading speed was accepted as the criterion for significant improvement, more children from the autism group increased reading speed than children from the age- and intelligence- matched control group. However, inspection of individual data showed that many of the children with autism increased reading speed at higher levels. Thus whilst 79% of the children with autism read more than 5% faster with overlays, 67% of these children increased reading speed at rates ranging between 11% and 50% with overlays. The range of improvement in the small proportion of controls who did reach or exceed the 5% improvement criterion was smaller, spanning 8 – 25%. Research using colour overlays with normal populations has shown a 5% increase in 20% of individuals (Wilkins et al., 2001), a finding consistent with those from the current study where 16% of controls showed an increase of more than 5% with overlays. However, the numbers of children within the autism group who improved in reading speed using colour overlays was significantly larger, and the range of improvement greater than that seen in the control group.

Although research has shown that children who are poor or slow readers are more likely to improve in reading performance when using overlays than children without reading difficulties, this tendency is weak (Wilkins et al., 2001). The children with autism in the present sample did not show poor reading skills when reading without a colour overlay. Indeed, their initial reading scores and those of their age and verbal IQ matched controls did not differ significantly. This showed that not only were the groups matched well for reading ability, but that reading scores without an overlay did not predict performance with an overlay. There was no correlation for either group between BPVS scores and the number of words read with and without an overlay. Therefore, verbal IQ did not appear to contribute to improvement with an overlay. However for the group with autism, there was a significant correlation between age and number of words read with and without an overlay. Children with autism showed better performance on this task with increasing age irrespective of using an overlay.

All the children with autism reported that the coloured overlays made the text clearer, whilst none reported a preference for the white (no overlay) text. Sixteen of the nineteen children in the control group reported a preference for coloured overlays, and three preferred the white text. All children who chose an overlay (both those with autism and controls) reported significantly fewer symptoms of visual stress when the overlay was used for reading. In the present study, those who read more than 5% faster with the overlay also reported fewer symptoms of visual stress with the overlays. However, this failed to reach statistical significance. Wilkins et al., (2001) found a correlation between the number of symptoms of visual stress and an increase in reading speed with an overlay in his sample of normal children. However, no such effect was found in the current study. Although none of the participants in the present study asked for clarification on any of the visual stress questions, comprehension difficulties are characteristic in autism and may have contributed to the non-replication of the Wilkins et al's earlier finding. Verbal self-report measures may not be the best method for assessing symptoms of visual stress in autism, particularly where there is co-occurring intellectual impairment.

It was noted that no single colour was chosen more often than any other, and there was a great dispersion of colours choices. This is shown in Appendix 1. The most frequently selected colour was mint green with 18% of the children (both controls and children with autism) selecting this colour. Similarly there was no tendency to choose either single or double overlays, and 47% of the total sample, including 57.8% with autism and 36% of controls, chose a double overlay. These findings are in line with those from other studies showing wide variation in colour choice. For example, Wilkins et al., (2001) carried out a large scale study of typically developing children and found that overlay choice was widely distributed among the colours available, and that the most frequently selected colours (rose and aqua) were chosen by less than 10% of the sample. However, it was noted in the study that the participants showed remarkable consistency in their colour choice across different testing sessions. As the participants will carry out further tasks using colour overlays this will be further discussed.

It was surprising that the results from the Ishihara and City University colour test showed that children who benefit from colour overlays do not have anomalous colour vision. However, this finding is in line with previous studies suggesting that the prevalence of colour vision anomaly in individuals with Meares-Irlen syndrome is similar to that in the general population (Evans et al., 1996; Evans et al., 1996).

This is the first empirical study to show that reading skills in autism are improved by the use of colour overlays. Important outstanding questions relate to whether colour overlays will enable children with autism to improve performance on other tasks. A question that has significant importance clinically is whether children with autism who have marked intellectual impairment will show similar gains when using a colour overlay. Therefore in the following chapter, experiments investigating the use of colour overlays on a written comprehension task as well as a non-linguistic visual cognition task will be described.

CHAPTER THREE

TESTING SINGLE WORD READING, COMPREHENSION AND VISUAL SEARCH WITH AND WITHOUT COLOUR OVERLAYS.

Summary: In the previous chapter findings showing that the use of coloured overlays improved both reading speed and accuracy in children with autism were presented. In the first study to be reported in this chapter eighteen of the children with autism who had participated in the previous study, together with their age and intelligence matched controls, were retested eight months later to assess the reliability and consistency of these findings. A short comprehension task was also carried out in order to test whether these overlays would improve not only reading speed and accuracy, but also the children's understanding of the text. The findings from these studies showed that 76% of children with autism read faster on both the reading and comprehension tasks with an overlay in comparison to only 6% of controls. In order to test low functioning children with reading difficulties with overlays, a visual feature change detection task was constructed. The findings from this study showed that a significantly greater number of children with autism (73%) completed the task quicker with than without an overlay compared to controls (34%). There was no significant effect of intelligence, and cognitively impaired children were as likely to improve task performance using an overlay as cognitively unimpaired children. The findings are discussed within the framework provided by the cortical hyperexcitability theory (Wilkins, 2003) and neuropsychological accounts of autism.

INTRODUCTION

In the previous chapter, findings showed that more children with autism than controls increased reading speed for single words when using colour overlays. This chapter aims to replicate and extend these findings by investigating reading at the sentence level with and without overlays. As a large proportion of children with autism also show co-occurring intellectual impairments, the question of how their task performance will change when using colour overlays is of clinical significance. Therefore cognitively unimpaired children with autism (HFA), cognitively impaired children with autism (LFA), typically developing children (TD) and children with moderate learning difficulties (MLD) will complete a non-verbal task that does not require reading ability with and without overlays.

Research shows that many autistic children acquire some level of reading skill (Lockyer & Rutter, 1969; Rutter & Barktak, 1973; Cobrinik 1974; Bartak & Rutter, 1975). However, these skills show qualitative differences to those of typically developing children (Happé, 1997; Snowling & Frith, 1986). For example, whilst decoding skills are in evidence in intellectually unimpaired individuals, they show great variation and may be below, equal to or above chronological age norms (Eskes, Bryson & McCormick, 1990; Frith & Snowling, 1983; O'Connor & Hermelin, 1994). Children with autism have also been found to use phonetic strategies in order to decode words (Frith & Snowling, 1983). However, studies typically reveal a pattern of good word identification with poor comprehension (Goldberg, 1987; O'Connor & Hermelin, 1994).

Single word reading comprehension has been found to be largely intact in autism (Frith & Snowling, 1983; Eskes, Bryson &McCormick, 1990), a finding confirmed in experiment one in chapter two presented in this thesis. Although many individuals are able to use syntactic context (Frith & Snowling, 1985), acquisition of grammatical skills tends to be delayed relative to other skills (Tager-Flusberg, 1981; 2001; Tager-Flusberg, Calkins, Nolin et al., 1990). Indeed, Kjelgaard & Tager-Flusberg (1999) found that only 25% of a sample of 80 children with autism with nonverbal IQ scores in the normal range, achieved standardised measures of grammatical ability that were in the normal range. The findings from the study also showed that a quarter of the sample obtained scores that were more than two standard deviations below the mean (Kjelgaard & Tager-Flusberg, 1999). Reading comprehension scores typically tend to be lower than reading accuracy scores in autism (Lockyer & Rutter, 1969; Rutter & Bartak, 1973; Frith & Snowling, 1983), and it seems likely that grammatical complexity contributes to poor comprehension ability.

Whilst some studies have shown that phonology, semantics and syntax are reading and mental age appropriate in autism (Bartolucci, Pierce, Streiner et al., 1976; Frith & Snowling 1983; Tager-Flusberg et al. 1990; Minshew, Goldstein & Siegel, 1995), difficulties in appreciating 'meaning' appear to be universal. In fact, such difficulties reflect core diagnostic abnormalities in communication. In one study, Prior and Hall (1979) found that their participants with autism selected words that were syntactically appropriate but often semantically inappropriate (Frith & Snowling, 1983). However, the comprehension of single words showed no abnormalities. In homograph tasks, where typically developing participants use sentence context as the primary cue to correct pronunciation, participants with autism typically show poor performance (Frith

& Snowling, 1983; Happé, 1997). In addition, individuals with autism have been found to possess poorer appreciation of humour in comparison to those with typical development (Emerich, Creaghead, Gtether et al., 2003).

Difficulties in using context in autism has been interpreted as providing evidence for weak central coherence (WCC) (Frith, 1989; Happé, 1999) outlined in the introductory chapter. This theory predicts that autism is characterised by a processing bias that favours local features at expense of global, context dependent meaning or Gestalt. Individuals may therefore fail to comprehend what they read because of a weak tendency to integrate information in order to abstract gist. Other potential explanations for this failure include difficulties in switching attention among parts of a task (Courchesne, Akshoomof, Townsend et al., 1994; O'Connor & Hermelin, 2004), or from the local to the global level (Plaisted et al., 1999; O'Connor et al., 2004). It has also been suggested that comprehension can be inhibited by a tendency towards distractibility and literalness (Attwood, 1998; Falk-Ross, Iverson, Gilbert et al., 2004).

In the introductory chapter the underconnectivity theory (Just, Cherkassky, Keller et al., 2004) was outlined, and this might provide a neurological explanation for why children with autism exhibit poor comprehension skills. A number of cortical areas have been shown to be activated during sentence comprehension in typically developing individuals. For example, Broca's area has been shown to be involved in a number of processes that could play an integrating role in sentence comprehension. Such processes include syntactic processing (Caplan, Alpert & Waters, 1998; 1999; Friederici, Meyer & von Cramon, 2000; Just, Carpenter, Keller et al., 1996; Keller, Carpenter & Just, 2001; Ni, Constable, Menci et al., 2000; Roder, Stock, Neville et al, 2002); semantic processing (Fiez 1997; Fiez & Petersen, 1998; Gabrieli, Poldrack & Desmond, 1998) and working memory functions (D'Esposito, Postle, Ballard et al., 1999). The area immediately surrounding the posterior left superior temporal sulcus (including the superior temporal and middle gyri) has also been shown to be strongly involved in sentence comprehension (Just et al. 96; Roder et al. 2002).

Just et al., (2004) used functional MRI to measure brain activation in a group of autistic participants and verbal IQ matched controls during sentence comprehension. They found that the group with autism showed more activation in Wernicke's (left laterero-superior temporal) area and less activation in Broca's area (left inferior frontal gyrus) than controls. The findings also showed that the functional connectivity was lower throughout the cortical language system in autistic participants than in controls, suggesting that levels of co-ordination and communication between cortical areas are lower in autism (Just et al. 2004). The authors propose that these abnormalities may be the locus of WCC in that cognitive strengths tend to be seen on focused tasks such as word reading, which may require relatively less coordination among cortical areas. In contrast, sentence and story comprehension, which require larger scale integration of cortical function, are frequently poor in autism.

One type of task on which participants with autism consistently show superior performance in comparison to controls is the visual search task. Typically, in these tasks participants are required to detect a target item that differs from distractor items along a single dimension. Such an example would be to search for red X's among red T's and green X's. In one study using this paradigm, children with autism showed superior performance in comparison to age and intelligence matched controls (Plaisted, O'Riordan & Baron-Cohen, 1998). The issue of superior visual search will be further investigated in a change detection task to be presented in this chapter.

The underconnectivity model (Just et al., 2004) predicts that any facet of psychological or neurological function that is dependent on the coordination or integration of brain regions is susceptible to disruption, particularly when the computational demands of the coordination are large (Just et al., 2004). A number of neurobiological findings of brain dysregulation in autism have been reported that could be a basis of the altered pattern of fMRI activity and functional underconnectivity in autism. These include structural abnormalities involving total brain volume, the cerebellum and, recently, the corpus callosum. The evidence in favour of disturbed neural networks in autism has implicated dysfunction in both cortical and subcortical areas, including temporo-parietal cortex, the limbic system, the cerebellum, as well as prefrontal regions (Brambilla, Hardan, Ucelli di Nemi, et al., 2003; Aylward, Minshew, Field et al., 2002; Bailey, Le Couteur et al., 1995; Carper Moses, Tigue et al., 2002; Courchesne, 2002; Lainhart, Piven, Wzorek et al., 1997).

The findings from these studies provide evidence for wide ranging neurological abnormalities in autism. The question to be asked here is how the findings from chapter one, showing improvements in reading when using colour overlays, can be interpreted within the context of these reported abnormalities. According to the cortical hyperexcitablity theory (Wilkins, 2003) outlined in the introduction, self selected colour overlays result in improvements in reading in individuals with central nervous system disorders, because self selected colours reduce activation in overactive areas. It seems plausible to suggest that the extent of overactive areas may be more or less circumscribed across disorders and may be fairly widespread in autism. Indeed, research suggests sensory abnormalities in autism are not limited to the visual system (Cesaroni & Garber, 1991; Dunn, 1999; Kientz & Dunn, 1997; Williams, 1999).

The experiments presented in this chapter will attempt to address two main questions. First, given the numbers of high functioning individuals with Autistic Spectrum Disorder (ASD) currently attending mainstream schools and enrolled in tertiary education (Burack, Root & Zigler, 1997; Gerhardt & Holmes 1997; O'Connor & Klein, 2004) the question of whether overlays might facilitate reading performance beyond the single word level is of considerable interest educationally. A second question is whether the use of colour overlays might benefit children with autism and intellectual impairment, who are not able to read and were therefore not tested on the Rate of Reading task in experiment one. The first two studies to be presented will attempt to replicate and then extend previous findings of improvements in reading when using a coloured overlay. The third experiment will use a non-verbal task that is appropriate for use with lower functioning children who may not be able to read.

EXPERIMENT TWO: TESTING THE RATE OF READING: A REPLICATION

Participants

Eighteen children with ASD participated in the study. They were aged between 9 years 0 months and 15 years and 10 months (mean 12 years and 6 months) and attended schools for which a formal diagnosis of ASD was the criterion for entry. Their scores on the British Picture Vocabulary Scale, (BPVS) (Dunn et al., 1997) ranged between 47 and 87 (mean 64.5). Typically developing (TD) control participants were individually matched to the children with autism for chronological age, gender and verbal IQ as measured by the BPVS. The children's psychometric and age data are shown in Table 3.1.

Table 3.1: Age, Verbal IQ data for children with autism and controls

Group	Age		BPVS	
	Mean	sd	Mean	sd
Children with Autism (N=18)	12.3	(2.13)	64.50	(11.20)
TD (n=18)	12.1	(1.88)	68.30	(11.26)

Materials

The materials were the same as used in chapter one. These included the *Intuitive Overlays* (Wilkins 1994) and the Rate of Reading Test (Wilkins et al., 1996). The published test exists in two versions that differ only as regards typeface, size and spacing. Again in this study the larger text (14pt Geneva) was used.

Procedure

The Procedure was exactly the same as used in chapter one.

Results

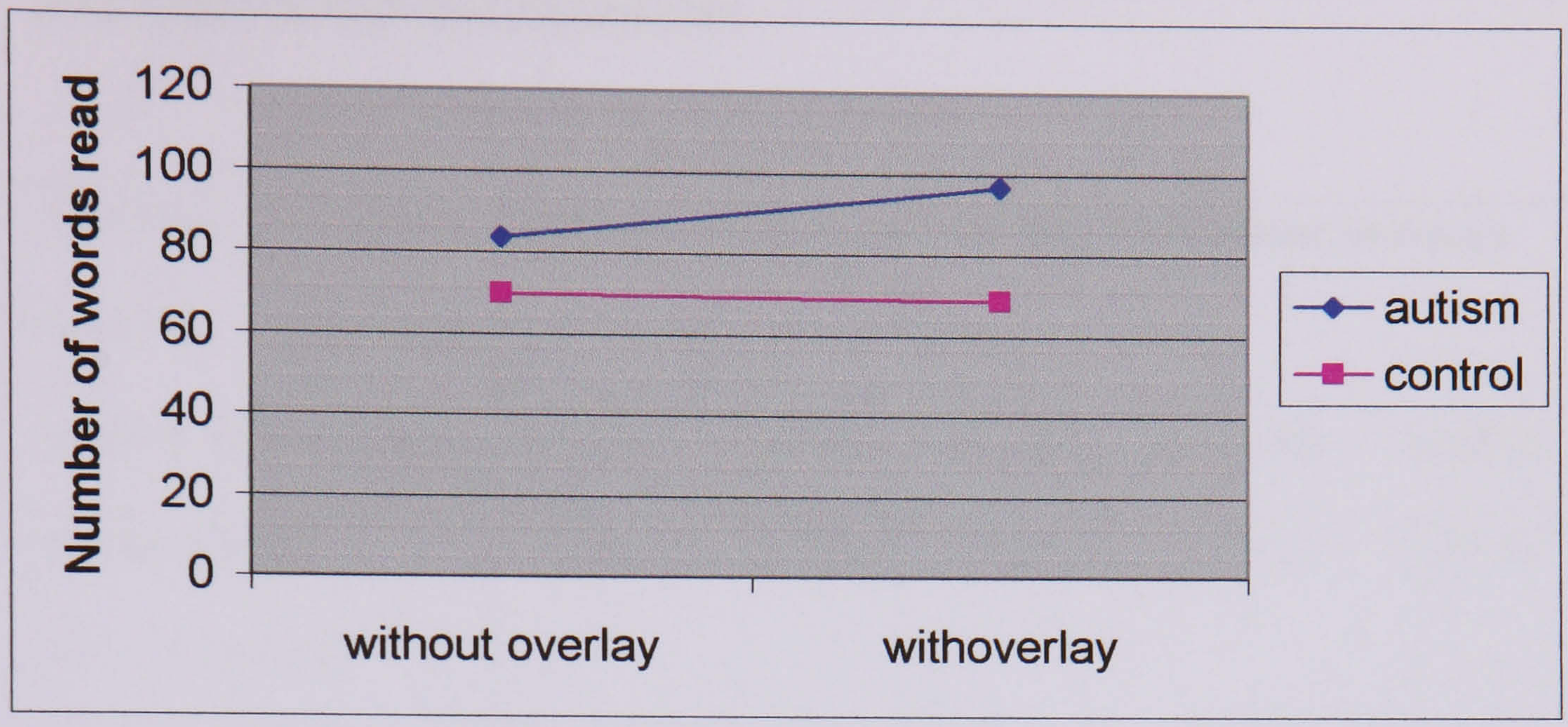
The means and standard deviations for reading rates with and without colour overlays are shown in table 3.2 below.

Table 3.2: Means and standard deviations for reading rates with and without colour overlays for children with autism and controls.

Group	Words read per minute with colour overlay		Words read per minute without colour overlay	
	Mean	sd	Mean	sd
Autism=18	96.9	33.7	83.8	32.2
Controls=18	68.6	17.4	69.8	19.8

A 2*2 ANOVA with Group (autism/controls) as the between group factor and condition (number of words read per minute with and without overlays) as the within group factor revealed a significant main effect of condition ($F(1,34)=20.08$, $p<.001$), a significant main effect of group ($F(1,34),=5.74$, $p<.05$) and a significant group x condition interaction ($F(1,34)=29.69$, $p<.001$) which is shown in figure 3.1 below.

Figure 3.1: Group x condition interaction



This interaction was analysed using paired t-tests with Bonferroni adjustments. These showed that children with autism read significantly more words per minute with than without an overlay ($t(17)=6.23$, $p<.001$), whereas there was no significant difference across conditions for controls ($t(17)=-.802$, n.s.). The children with autism read significantly faster than controls both with colour overlays ($t(34)=3.17$, $p<.001$) and without overlays ($t(34)=1.57$, $p<.05$).

Again a 5% increase in reading speed as the criteria for significant effects was set (Wilkins, 2003) and an initial analysis, using a 2*2 chi-square, was carried out in order to determine whether more children with autism would achieve criteria than controls. This showed that significantly more children with autism read faster at the 5% level with the overlays than controls($\chi^2=16.00$; df=1, $p<.001$). Again, inspection of individual data showed that many children improved at higher levels than this. These data are shown in table 3.3 below.

Table 3.3: The degrees of improvement in reading in the group with autism and their controls with a colour overlay

Numbers of children showing improved reading with overlays	Degrees of improved reading with colour overlays				
	5-10%	11-20%	21-30%	31-40%	41-50%
Autism (n=15) (83% of sample)	5 (28%)	2 (11%)	5 (28%)	2 (11%)	1 (6%)
Controls (n=3) (17% of sample)	2 (11%)	0	0	1 (6%)	0

As can be seen from table 3.3, 56% of the children with autism improved reading speed at a level that was greater than 10% whereas this was only the case for 6% of controls.

There was no significant between group difference in the number of symptoms of visual stress reported with and without an overlay ($t(34)=0.01$, n.s.). Data from the participants with autism did not show a significant difference in the number of stress symptoms reported in overlay/no overlay conditions ($t(17)=2.06$, n.s.), and this was also true for controls ($t(17)=1.71$, n.s.).

Correlations carried out on the BPVS scores and the number of words read per minute with an overlay ($r=-.38$, n.s.) and without an overlay ($r=-.29$, n.s.) were not significant for the autism group. However, as for experiment one there was a significant correlation between age and the number of words read with an overlay ($r=.68$, $p<.05$) and without an overlay ($r=.62$, $p<.05$) for this group. For controls there was no significant correlation between BPVS scores and number of words read per minute with an overlay ($r=.44$, n.s.) although this was significant in the no overlay condition ($r=.49$, $p<.05$). There was no correlation between age and the number of words read with an overlay ($r=.26$, n.s.) or without an overlay ($r=.34$, n.s.) for controls.

EXPERIMENT THREE - COMPREHENSION TASK

Participants

With the exception of one child from the ASD group and one from the TD group, the participants were the same as for experiment two.

Materials

The intuitive overlays (Wilkins 1994) (as described in experiments one and two) were again used. The SCOLP (Baddeley, Emslie, Nimmo-Smith, 1992) is a language comprehension test that requires children to read lists of sentences (eg "fruit grows on trees", "we eat shoes") and judge whether they are true or false. The test included four sheets of text with 20 sentences on each one.

Procedure

The overlay selection procedure, as described in experiment one, was repeated using the sheets of text from the SCOLP. The SCOLP included four lists of words (A list 1 and 2; B list 1 and 2) and children either completed both parts of list A with an overlay and both parts of list B without an overlay or visa versa. The order was randomised across and within groups. The children's correct responses and completion speed for each were summed. Visual stress symptom questions (see experiment one) were again administered.

Results

The means and standard deviations for correct responses to the sentences task are shown in table 3.4.

Table 3.4: Means and standard deviations for correct responses for experiment three.

Group	With a colour overlay		Without a colour overlay	
	Mean	**sd**	**Mean**	**sd**
Autism	38.2	(2.4)	38.3	(2.5)
Controls	38.8	(2.2)	38	(4.2)

*Maximum number correct = 40

A 2*2 ANOVA was carried out on the data. Group (autism/controls) was the between factor and condition (scored with and without overlays) as the within group factor. The analysis showed no significant main effect of condition $F(1,32)=1.90$, n.s.) or group $F(1,32)=1.94$, n.s.), and there was also no significant interaction ($F(1,32)=0.34$, n.s.).

The means and standard deviations for time taken to complete the comprehension task are shown in table 3.5.

Table 3.5: Time taken to complete the comprehension task with and without overlays

Group	Time completed (seconds) With an Overlay Mean	Sd	Time completed (seconds) Without an Overlay Mean	Sd
Autism	182	(83.9)	202	(110.5)
Controls	240	(68.3)	239	(74.1)

A 2*2 ANOVA with group (autism/controls) as the between subjects factor and condition (time taken to complete task in seconds with and without overlays) was the within group factor. The analysis showed no significant main effect of condition ($F(1,32)=2.24$, n.s.) or group ($F(1,32)=2.18$, n.s.) and there was also no significant group x condition interaction ($F(1,32)=2.74$, n.s.).

Although ANOVA failed to reveal a significant difference in mean completion times between the groups when using a colour overlay, inspection of the data showed that the pattern of performance within the groups was very different. This showed that fourteen of the seventeen children with autism (82%) completed the comprehension task faster with an overlay, whereas this was the case for only six of the seventeen children (35%) in the control group. A 2*2 Chi square confirmed that significantly more children from the autism group completed the task faster with colour overlays than from the control group, ($\chi^2= 7.77$; df=1, $p<.05$).

In experiment one, the initial criteria for comparing differences was set at 5% improvement in reading with overlays. Therefore, in order to maintain consistency across experiments, analysis of the data for numbers of children showing a greater than 5% increase in completing the SCLOP with a colour overlay was carried out. As table 3.6 below shows, 42% of children from the autism group completed the task over 10% faster with the overlays in comparison to 18% of the controls. However, the difference at the 5% level failed to reach significance (χ^2= 1.12; df=1, p=.29).

<u>Table 3.6: The degrees of improvement on the comprehension task in the group with autism and their controls with a colour overlay</u>

Numbers of children showing improvement on comprehension task with overlays at 5% level or more	**Degrees of improved reading with colour overlays**			
	5-10%	**11-20%**	**21-30%**	**31-40%**
Autism 8 (out of 17) (47%)	1(6%)	4(24%)	2(12%)	1 (6%)
Controls 5 (out of 17) (29%)	2(12%)	3(18%)	0	0

There was no significant between group difference in the number of symptoms of visual stress reported with and without an overlay ($t(32)=-.15$, n.s.). There also was no significant difference in the number of symptoms of visual stress reported across the two conditions in the autism group ($t(16)=1.28$, n.s.). However, the control group reported significantly fewer symptoms without than with the overlay ($t(16)=2.49$, $p=.05$).

Correlations carried out on the data showed that for the autism group, there was no correlation between BPVS scores and time taken to complete the task with an overlay ($r=-.06$, n.s.) or without an overlay ($r=-.08$, n.s.). There was no correlation between age and the time taken to complete the task with an overlay ($r=.14$, n.s.) or without an overlay ($r=.005$, n.s.). For the controls there was no correlation between BPVS scores and time taken with an overlay ($r=-.047$, n.s.) or without an overlay ($r=-.034$, n.s.). There was no correlation between age and the time taken with an overlay ($r=-.39$, n.s.) but this was significant in the no overlay condition ($r=-.59$, $p<.05$).

COMPARING PERFORMANCE ACROSS EXPERIMENTS TWO AND THREE

This showed that eight of the seventeen children with autism (47%) and two of the seventeen control children (12%) improved performance speed by more than 5% on both the rate of reading and the comprehension tasks. This difference was statistically significant ($\chi^2= 5.10$; df=1, $p=.05$). The consistency of colour choices across the two testing phases was high, with 94% of the children with autism and 88% of the controls choosing the same colour on both occasions.

EXPERIMENT FOUR: PERFORMING A VISUAL CHANGE DETECTION TASK WITH AND WITHOUT COLOUR OVERLAYS.

Participants

As a major aim of this study was to test lower-functioning children with ASD and the linguistic demands in experiment four were low, participants were matched to controls on the basis of non-verbal IQ measured using Ravens Matrices and age. Subject data are shown in table 3.7.

Table 3.7: Age and IQ data for participants in experiment four

Group	Age		Ravens Matrices	
	Mean	sd	Mean	sd
ASD GROUP (n=26)	12.3	2.21	75.8	16.23
HFA (n=13)	12.2	2.31	89.6	11.61
LFA (n=13)	12.4	2.17	61.85	5.29
Control Group (n=26)	12.3	2.11	74.23	15.25
TD (n=13)	12.1	2.32	86.0	13.24
MLD (n=13)	12.4	1.96	62.4	3.02

Materials

The intuitive overlays (Wilkins, 1994) were again used in experiment four. 70 pictures of everyday objects, each with similar levels of detail and familiarity, were taken from the Snodgrass and Vanderwart (1980) picture scale. Each picture was copied onto an A4 sheet of paper, seven times in a row with a large gap between the first (target pictures) and the remaining pictures, which were evenly spaced with smaller gaps. Five of the six non-target pictures were altered so that a part of the pictures was either deleted, added-to or shaded. An example is shown in Figure 3.2 below.

<u>Figure 3.2 - Change Detection Task - Sample</u>

In order to avoid order effects, the position of the picture that was identical to the target was randomised within stimulus sets. As for experiment 3, the stimuli were arranged in two sets (A1 & 2, B1 & 2) and children completed one set with and one set without an overlay. As for experiment three, this was randomised within groups. The procedure for choosing an overlay was the same as for experiments one and two, except that the picture stimuli replaced the pages of text. The children were instructed to find the picture that was identical to the target picture as quickly as possible. Accuracy scores and speed data were recorded and were summed across stimulus sets.

Results

The means and standard deviation for correct responses for experiment four are shown in table 3.8

Table 3.8: Mean and Standard Deviations for Accuracy scores on Change Detection Task

Group	With a colour overlay		Without a colour overlay	
	Mean	sd	Mean	sd
Autism (N= 26)	26.8	4.4	26.4	3.9
Controls=26	26.1	3.3	25.7	3.2

***Maximum number correct =30**

A 2*2 ANOVA was carried out on the data with group (autism/controls) as the between subjects factor and condition (number of pictures correctly identified with and without overlays) was the within group factor. The analysis showed no significant main effect of condition ($F(1,50)=1.25$, n.s.) or group ($F(1,50)=.48$, n.s.) and no significant interaction ($F(1,50)=.025$, n.s).

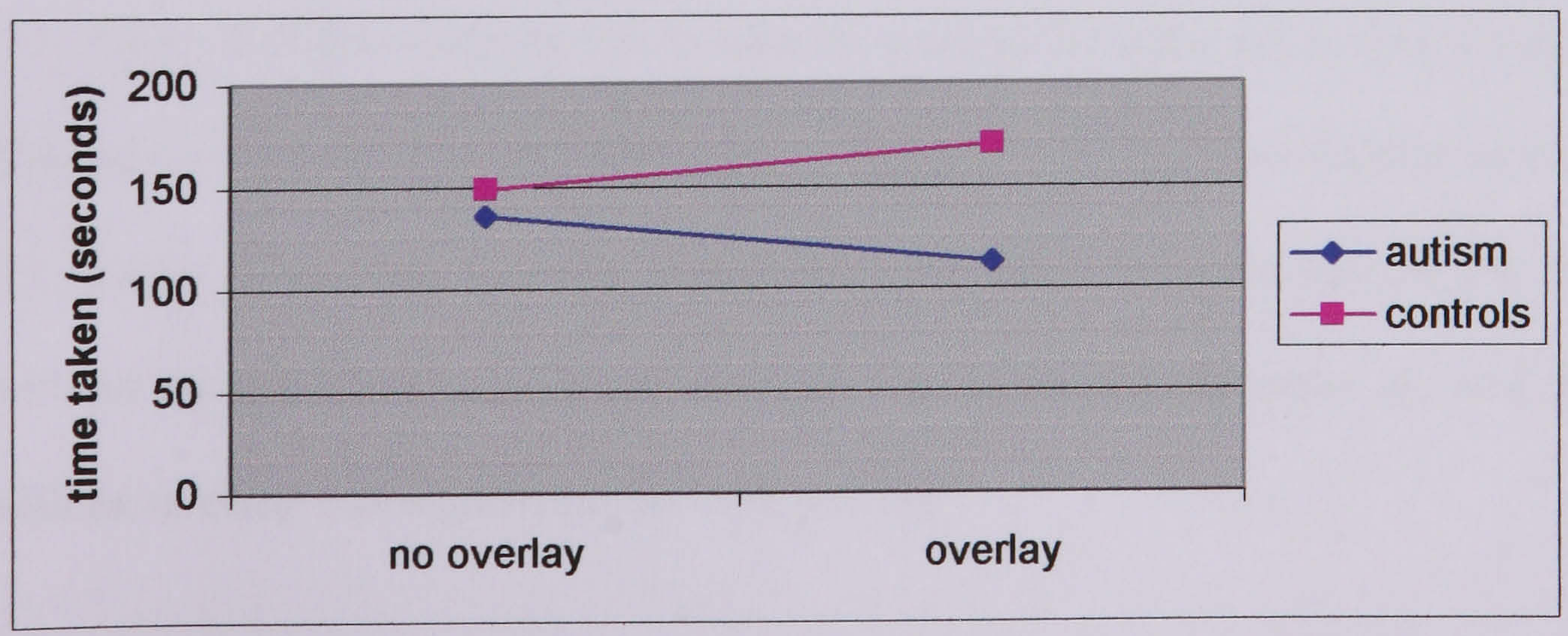
The means and standard deviations for time taken to complete the task are shown in table 3.9 below.

Table 3.9: Mean and standard deviations for time taken to complete change detection task for control group and group with ASD.

Group	Time taken (seconds) with colour overlay Mean	sd	Time taken (seconds) without colour overlay Mean	sd
Autism (N=26)	112.91	56.95	135.67	60.05
Controls (N=26)	170.28	92.64	148.74	89.59

A 2*2 ANOVA was carried out on the data. Group (autism/controls) was the between group factor and condition (completion times with and without overlays) was the within group factor. This analysis showed no significant main effect of condition ($F(1,50)=.009$, n.s.) or group ($F(1,50)=3.02$, n.s.). However there was a significant group x condition interaction ($F(1,50)=12.170$, $p<.001$) which is shown in figure 3.3 below.

Figure 3.3: Group by condition interaction for change detection task



The significant interaction was analysed using paired t-tests. This showed no significant between group difference (autism/controls) was found when children completed task without colour overlays ($t(50)=0.61$, n.s.), but children with autism completed the task faster than controls with colour overlays, ($t(50)=-2.69$, $p<.05$). There was no significant difference in time completed with and without an overlays for the autism group ($t(25)=.83$, n.s) or for the controls ($t(25)=.75$, n.s.).

As was the case for experiments one and two, a significantly greater number of children with ASD than controls completed the task 5% faster with an overlay than without one, and this was significant ($\chi^2= 7.74$; df=1, $p<.05$). Within the ASD group there were no significant differences in the number of high functioning and low functioning children with autism who increased speed when using an overlay ($\chi^2=.016$; df=1, n.s). There was also no intelligence dependent difference (TD and MLD) within the control group ($\chi^2= .170$; df=1, n.s.).

Correlations were carried out on the data. These showed that for the autism group, their scores on the Raven's Matrices scores did not correlate with time taken with an overlay ($r=-.068$, n.s.) or without an overlay ($r=-.027$, n.s.). There was no correlation between age and the time taken with an overlay ($r=-.24$, n.s.) or without an overlay ($r=-.30$, n.s.). For the controls, there was no correlation between scores on the Raven's Matrices scores and time taken with an overlay ($r=-.01$, n.s.) and without an overlay ($r=-.11$, n.s.). There was also no significant correlation between age or the time taken without an overlay ($r=-.35$, n.s.), although the correlation between age and time taken with an overlay was significant ($r=-.49$, $p<.05$).

DISCUSSION

The findings from the experiments presented in this chapter confirmed the findings from experiment one in that they showed significantly more children from the autism group than from the control group increased their performance speed on the rate of reading and comprehension tasks when using colour overlays. Thus, 82% of children with autism increased speed on the sentence classification task, and of these 76% increased speed on single word reading as well. In contrast, 11% of controls showed a significant increase in speed on the rate of reading test, 35% increased speed on the comprehension test and of these 6% read faster on both. Importantly, increases in speed did not co-occur alongside a reduction in accuracy in either group. These findings confirm that colour overlays are of significant therapeutic benefit for children with autism. In experiment four that had been designed for use with cognitively lower functioning children, 69% of these reduced task completion times with the overlays, a finding that mirrored the results from the high functioning children with autism, 76% of whom also reduced task completion times. Within the control group, a similar proportion of MLD and TD children reduced reaction times with overlays (MLD = 38%; TD = 30%), although the effect was far smaller than had been recorded for the autism groups. Indeed, the frequency improvement in the control group was consistent with that found in previous studies with typically developing children (Wilkins et al., 2001). Again, no speed accuracy trade off was seen in experiment four for either participant groups.

Although the group with autism was matched to the control group for verbal intelligence as well as age and gender in experiments two and three, it was noted that the mean number of words read per minute was higher for the autism group in experiment two, even without a colour overlay. However it seems unlikely that single word reading is superior in children with autism. Previous research has shown that single word reading comprehension is unimpaired in autism (Eskes et al., 1990; Frith & Snowling, 1983; Prior & Hall, 1979), and it may be the case that they can outperform typically developing children when words are presented without context. Before beginning the Rate of Reading task, the children were told that the passage they were to read did not make sense and they were also given practice trials. However, reading passages of single words without context may be more difficult for typically developing children, and it was noted that several participants were unenthusiastic about completing the test. A weaker reliance on context may also have influenced the findings from experiment three. The comprehension test used in this experiment (SCOLP, Baddeley et al., 1992) included "silly" sentences and children had to judge whether or not these were correct. Research has shown that individuals with autism have difficulties in appreciating humour (Emerich et al., 1993), and this would have meant that they would be more likely to judge the correctness or incorrectness of the sentences without distraction. Thus, whilst difficulties in sentence comprehension are commonly noted in autism (O'Connor & Hermelin, 1994; Patti & Lupinetti, 1993; Happé 1997), performance might more nearly equal that of typical children in situations where a weaker tendency to process global context conveys an advantage. Children without autism would be more likely to process the humorous aspect of the stimuli, and this may have been distracting in some cases. Indeed some of the participants in the control group did remark on the "silliness" of some of the sentences. However the accuracy scores for both groups were very high, and it may be the case that group differences would have emerged on a more difficult task. The main aim of the experiment was to ascertain whether or not overlays could improve reading comprehension in children with autism, and the findings of increased reading speed together with a high level of accurate responses suggest that this is the case.

One important finding from the studies was that 94% of the children with autism and 88% of control children selected the same coloured overlay at both times of testing (experiments two and three). Wilkins (2003) has proposed that visual stress and distorted perception, sometimes reported in autism and disorders affecting the central nervous system, occur when a spread of activation within the cortex causes cells to fire inappropriately. As this theory predicts that the locus of hyper-excitability varies across individuals, and only specific colour filters can change the distribution of the firing, the process of selecting an overlay was an important aspect of the experiments presented in chapters two and three. In a previous study using colour overlays, a significant correlation between reported symptoms of visual stress and reading improvement with an overlay was reported (Wilkins et al., 2001). However, in the current studies reported levels of visual stress symptoms were low and there was no significant difference between the autism and control groups. Evidence presented in the introduction to the thesis (e.g. Gillberg & Coleman, 1992; White & White, 1987) and the findings from experiment one presented in chapter two strongly suggests that at least some individuals with autism experience visual stress and perceptual distortion. It may be then be the case that the methods previously used to obtain this information are unsuitable for use with children with autism. Clearly, alternative methods for evaluating visual stress in individuals with communication difficulties should be developed.

In experiment four participants completed a simple change detection task. Previous studies testing visual search have frequently found superior performance in autism relative to controls (e.g. Plaisted, 2001). However in the current study there were no group differences in accuracy scores. The analysis of the time to complete the task showed a significant interaction whereby participants with autism did not complete the task faster than controls in the 'no overlay' condition, but were significantly faster than them when using an overlay. The chi square analysis showed that more children from the autism group than the control group increased speed using an overlay, and intellectual status did not show any significant effects. Thus, 76% of participants with HFA, 69% with LFA, 30% of TD controls and 38% of MLD controls completed the task faster in the overlay condition.

Taken together, the findings from the three studies presented in this chapter show that more children with than without autism increase reading and visual processing speed without costs to accuracy when using colour overlays. However, it was clear that not all children with this diagnosis showed this effect. It also appeared, from the correlation analyses, that better task performance with overlays did not occur more frequently in children within particular age ranges or with particular ability profiles (e.g. on Raven's matrices/BPVS). The only factor that was significant in the various analyses was diagnosis. The results from the City and Ishihara colour tests did not identify more colour vision abnormalities in the children with autism than controls. However, several recent group studies have reported a high incidence of sensory abnormalities, as measured by the Sensory Profile (Dunn, 1999), in children with autism (Dawson, 1983; Mayes & Calhourn, 1999; Myles et al., 2000). The relationship between sensory abnormalities measured by this test and other aspects of visual processing, with and without colour overlays, will be explored in a case study in chapter six.

Whilst the findings from the studies presented in this chapter show that children with autism do improve task performance with colour overlays, the question of why this should be the case remains unresolved. In the introductory chapter, the magnocellular deficit theory (Robinson & Foreman, 1999) and cortical hyper-excitability theory (Wilkins, 2003) were outlined. The first theory predicts that abnormalities in the magnocellular pathway will result in conflicting signals being received by the visual cortex (Gregory, 1994; Robinson & Foreman, 1999). As previously suggested, magnocellular abnormalities have been reported in dyslexia (Galaburda 1993; Iovino et al., 1998; Wilkins 2003), migraine (Wilkins 2003) and autism (Milne et al., 2002; Spence 2002). These are all groups that have been found to benefit from using colour filters or overlays (Wilkins 2003; Ludlow, Wilkins & Heaton, in press). However not all individuals who suffer from these conditions benefit from the use of overlays (Kriss 2002), and no study has yet identified a particular magnocellular abnormality in Meares Irlen syndrome (Evans et al., 1995; 1996; Simmers et al., 2001).

In the introduction the cortical hyperxcitability hypothesis was outlined and the question to be asked here is whether this theory can account for the findings presented in chapters two and three. The assumption that the cortex is hyperexcitable in autism is plausible given research showing abnormalities of cortical networks (Brambilla et al., 2003; Minshew et al., 2002; Bailey et al., 1993; Carper et al., 2002; Courchesne, 2003; Lainhart et al,. 1997), and less co-ordination and communication between cortical areas (Just et al., 2004). However, links between these research findings and cortical hyperexcitability have yet to be precisely outlined. Moreover, the behavioural consequences of atypical brain development in autism are currently not well understood, and the question of which of the various neuropsychological theories best accounts for the findings reported in this chapter remains open. An important question that can be addressed in experimental studies of autism, however, is whether atypical sensory processing in autism will result in abnormalities in processing colour information. This will therefore be tested in experiments investigating colour naming, colour discrimination and colour categorisation.

CHAPTER FOUR

INVESTIGATING COLOUR PERCEPTION AND NAMING, COLOUR DISCRIMINATION AND COLOUR CATEGORISATION IN AUTISM

Summary: Studies into colour processing in children with autism, intellectual impairment and typical development are presented in this chapter. The first of these tested colour naming and colour comprehension in autism and the findings showed that these abilities were largely unimpaired in the majority of children with this disorder. Experiment six tested the hypothesis that perceptual discrimination would be enhanced in autism. However the findings from the study failed to support the hypothesis, and group differences reflected intellectual level rather than diagnosis. Experiment seven sought to identify category boundaries for the different groups of participating children. Here, participants were required to label verbally colour chips drawn from the blue/green and blue/purple ranges. The findings from the study found that the children in the autism groups showed less consensus about which chips marked category boundaries. Categorical colour processing was further investigated in experiment eight. Here participants were required to identify the least similar of a group of three colour chips. The findings from this study showed that high and low functioning autistic participants differed from controls and from each other in defining category boundaries. For the intellectually unimpaired participants, category boundaries were narrower than for those of their typically developing matched controls, and for the cognitive impaired participants with autism these were looser of their mild learning difficulties matched controls. Theoretical accounts of autism, proposing that perceptual processing is

enhanced and results in narrow category boundaries, were rejected in favour of an account that emphasises the role of language in shaping colour perception.

INTRODUCTION

In chapters two and three it was shown that the use of a colour overlay greatly improved the performance of significantly more children with autism than matched controls on reading, comprehension and visual search tasks. It was concluded that the most likely explanation for why these overlays work is cortical hyper-excitability in autism. In the previous two chapters, the children with autism did not appear to show any colour abnormalities as evidenced by results from the City (Fletcher, 1998) and Ishihara (Ishihara, 1970) colour tests. However, it was still unclear whether abnormalities would be found on other colour tasks. In the studies to be presented in this chapter, children with autism and age and intelligence matched controls completed a colour naming task, a colour discrimination task and colour categorisation tasks.

Evidence from both autobiographies and clinical accounts strongly suggests that idiosyncratic reactions to colour are characteristic abnormalities in autism (Williams, 1992; White & White, 1991). Indeed, in response to these claims, various therapeutic interventions have been developed (Howlin, 1996; Irlen, 1991). Given this, it is surprising how little research into colour abnormalities in autism has been carried out.

Research into colour processing in typical populations shows that it is categorical in nature. Berlin & Kay (1969) were the first to propose that there exist at most, eleven universal basic perceptual colour categories onto which colour terms are systematically mapped. The eleven basic colour categories that they identified are white, black, red, green, yellow, blue, brown, pink, purple, orange and grey. Each of these colours is defined by a focal region representing the typical example of its category. The perceptual focal point for each colour category is remarkably concordant across languages that use that colour term. (Heider, 1972; Harkness, 1973; Collier, 1976; Uchikawa & Boynton, 1987; Boynton, Fargo, Olson et al., 1989; Uchikawa & Shinoda, 1996; Uchikawa & Sugiyama, 1993), and research has shown that with increasing distance from these focal colours and especially towards category boundaries, colours are less easy to name (Laws, 2002).

Cross-cultural studies have shown that focal colours are recognised more accurately and rapidly, and become associated with colour names more reliably than nonfocal colours (Heider, 1972; Rosch, 1973), and developmental studies have shown that children are more likely to select and are better at matching (Heider, 1971) comprehending and naming (Andrick & Tager-Flusberg, 1986), focal colours than non-focal colours. It has also been shown that young infants attend significantly longer to hue exemplars at the centres of the four basic hue categories (red, blue, green, yellow), than to boundary points between hues along the spectral continuum (Bornstein, 1975).

Some research suggests that infants have perceptual colour categories that are like the categories of adults (Bornstein, Kessen & Weiskopf, 1976; Teller, Peeples & Sekel, 1978). In fact, similar perceptual colour categories have been shown in animals (De Valois, Morgan et al., 1974) and in adults with extremely limited colour lexicons (Heider & Olivier, 1972). Thus before children engage in the learning of colour terms, they already possess colour percepts onto which colour concepts can be mapped (Pitchford & Mullen, 2003). Within the first few weeks of life, infants can distinguish colour differences (Allen, Banks & Narcia, 1993; Maurer & Adams, 1987; Morrone, Burr & Florentini, 1993; Teller, 1998; Teller & Bornstein, 1985), and by four months they show categorical perception for the four primary colours (Bornstein, Kessen & Weiskopf, 1976; Catherwood, Crassini & Freilberg, 1989) and some secondary colours (Franklin & Davies, 2004).

Colour is perceived as a number of discrete categories. Categorical perception (CP) occurs when stimuli from within a category are perceived as more similar than stimuli that fall over a category boundary (between category stimuli), even when stimulus separation sizes from within and between category stimuli are equal (Franklin, Clifford, Williamsonet al., 2005; Harnad, 1987).

The extent that language influences colour processing is controversial, and it has variously been suggested that colour categories are hardwired (Bornstein et al., 1976; Franklin & Davies, 2003), that they can be learned (Özgen & Davies, 2002), that they are shaped by verbal labels (Roberson & Davidoff, 2000), or are based on low level visual processes (Davies, Daoutis, Pilling et al., 2003; cited in Pilling & Davies, 2004; Kawai, Uchikawa & Ujike, 1995).

Linguistic relativists argue that categorical perception of colour is constructed through language (Whorf, 1956). In contrast universalists argue that the two systems (language/perceptual) map onto the pre-existing perceptual categories, but not all languages mark the same perceptual categories (Pilling & Davies, 2004).

The universalist theory is supported by evidence that colour categories are present before language and therefore may be innate (Bornstein et al., 1976; Catherwood, et al., 1989). Recently, Franklin, Pilling, and Davies (2005) found, by recording infants' eye movements on a target detection task, that infants as young as four months responded to colour stimuli categorically. This implies that colour categorisation is truly perceptual. Categorical effects are also shown by adults on perceptual tasks such as visual search tasks, where target pop out is thought to occur too quickly for a verbal strategy to be used (Davies et al., 2003; cited in Pilling & Davies; 2004; Kawai et al., 1995). Rosch (1973) in particular has argued that universal categories are each based on the same focal colours regardless of the number of terms in the speaker's language.

Although the brain structures responsible for colour categories have yet to be identified, cortical structures beyond the visual cortex are believed to be involved. It is possible that if categorical perception is hardwired, then these structures are tuned by the chromatic environment (MacLeod, 2002; Yendrikhovskij, 2001) such that by four months of age, adult-like categorical perception is in evidence. It is also possible that infant environments in the industrialised world are dominated by artefacts such as toys, clothes and pictures, in saturated primary colours that are close to category prototypes (Rosch, 1972). This may contribute to categorical perception in children as young as four months (Franklin, Clifford, Williamson et al., 2005).

The linguistic relativity theory leads to the prediction that categorical perception varies with language. Cross-cultural studies of categorical perception in adults lend support to this prediction (Kay & Kempton, 1984; Roberson, Davies & Davidoff, 2000). Most tests of the linguistic relativity hypothesis (LRH) involve a memory component and are particularly prone to direct language strategies (Kay & Kempton, 1984; Pilling, Wiggert, Özgen & Davies, 2003; Roberson & Davidoff, 2000). For example, a target colour could be remembered as a colour name, and recognition achieved by matching the retained name to the names of the colours in the recognition array. However CP is also found using simultaneous same-different tasks (Özgen & Davies, 2003) and visual search tasks (Daoutis, Franklin, Riddett et al., 2004; Pilling & Davies, 2004; Franklin, Pilling & Davies, 2004), where the memory load is minimal and labelling does not facilitate performance. The finding that cross category discrimination (stimuli having different names) is more accurate than within category discrimination also supports a direct language account (Pilling & Davis, 2004), as do findings showing that categorical perception can be eliminated by verbal interference (Roberson & Davidoff, 2000).

Although the physiological basis of colour vision is thought to be the same for humans with normal trichromatic colour vision (Mollan, 1999), there is considerable diversity in the ways that different languages segment the continuum of visible colour (Roberson, Davidoff, Davies et al., 2004). For example, the Dani of New Guinea have just two basic colour terms (BCT) (Heider 1972), most southern African languages have four or five BCT, and English has eleven BCT (Davies & Corbett, 1997). If the categorical effect is due to language, then differences should occur across the regions of colour space that are differently labelled by the speakers of the languages under investigation (Davies & Corbett, 1997).

Kay and Kempton (1984) compared Tarahumara (individuals from Mexico) whose language had a single term for the colour blue and green, with speakers of English on a 'triads' task. Participants were asked which of three colours from the blue-green border region was least similar to the other two. When two of the colours were both within either the blue or green category and the third chip was in the other, differences across groups appeared. The English speakers were more likely to choose the third chip (the one across their category boundary) as most different.

In another study looking at the effects of language, speakers of English, Russian and Setswana, who differ in the number of BCT they use and in how the blue/green region is categorised, were compared on a colour sorting task where colours were to be grouped for similarity. The English had eleven BCT (Berlin & Kay 1969), the Russians had twelve BCT (one more than Berlin & Kay's (1969) 'theoretical maximum'), and the Setswana had five BCT. A striking finding that was inconsistent with the linguistic relativity theory was the similarity across groups. However, the Setswana, who have a single term for blue and green ('botala'), were more likely to group blue colours with green colours than either the Russians or the English. But the Russians who have two basic colour terms for blue (light and dark) were no more likely than English speakers to separate light and dark blue (Davies & Corbett, 1997). Similar effects of language on grouping were found in a detailed exploration of boundary position within the blue/green region.

Pilling & Davies (2004) compared speakers of English and Ndonga (from rural northern Namibia) on three tasks. These languages differ in their number of basic colour terms and consequently in the positions of their category boundaries. The language Ndonga has six BCT with no basic terms for orange, pink and purple. The stimuli were chosen to exploit the language difference. On the sorting task (sorting into similarity groups) for each language, nominally similar colours were grouped together more often then nominally dissimilar colours. On the triad task (choosing the most different of three colours), groups tended to choose the nominally isolated colour for their language. On the search task (scanning for target colours among distractors), targets were either in a different English category than distractors (cross-category), or some targets were in the same English category (within-category). The within-category stimuli created greater difficulties for the English than for the Ndonga participants.

Davidoff, Davies & Roberson, (1999) and Roberson et al., (2000) have also found substantial differences in categorical perception across speakers of different languages. English speakers (eleven BCT) were compared to monolingual Berinmo speakers from three villages in Papua New Guinea whose language contains five BCT. Across three tasks (a similarity judgement task between three stimuli (Kay & Kempton, 1989), category learning and a recognition memory task), it was shown that categorical perception was consistently more closely aligned with the linguistic categories of each language than with the underlying perceptual universals (Davidoff, 2001).

There is also evidence that when colour names are not available, colour grouping becomes more difficult (Roberson et al., 2000). Language impairment resulting from brain damage has been found to make perceptual categorisation, including colour categorisation, more difficult (Goldstein, 1948; Roberson, Davidoff & Braisby, 1999). For example, patient L.E.W had marked difficulties with all types of spoken output although his comprehension skills were excellent (Druks & Shallice, 2000). He had normal colour vision and had no difficulty in recognising and interacting with objects (Roberson et al., 1999; Druks et al., 2000). However, L.E.W. could not name or comprehend colour names, and experienced great difficulty in sorting colours into groups. L.E.W.'s language impairment meant that he was reliant on a perceptual strategy for sorting tasks, and he revealed no effects of category boundaries (Davidoff, 2001).

The theory of perceptual reorganisation postulates that, whilst perceptual colour categorisation is hardwired and universal, language development reorganises locations of category boundaries at later stages in development (Franklin, Clifford, Williamson et al., 2005). Therefore, according to this account, both perception and language shape categories. Parallels in different domains can be found in developmental changes in speech (Werker & Tees, 1984) and spatial perception (Hespos & Spelke, 2004). This theory is also supported by category training studies (Goldstone, Lippa & Shriffrin, 2001; Özgen & Davies, 2002). Learning new colour categories over relatively short periods of time leads to the development of categorical perception for these specific categories (Özgen & Davies, 2002). This supports the position that during language learning (usually during infancy and childhood), the perceptual representation of colour is shaped by language learning. Discrimination around the category boundaries may improve relative to within category discrimination producing a 'warping' of perceptual colour space (Harnad, 1987).

Further support is provided by Roberson, Davidoff, Davies & Shapiro (2004) who compared a group of children from a equatorial African culture, whose language (Berinmo) contains five colour terms, with a group of English children. Despite large variations in the visual environment, language and education, the acquisition of colour vocabularies was gradual and initially perceptually driven. However, there was increasing influence of language in shaping category sets in culture-specific ways.

Recently, Franklin, Clifford, Williamsonet al., (2005) investigated a group of two to four years old Himba toddlers and found categorical perception to be independent of colour naming expertise and culture. Clearly this question merits continued investigation.

The study of colour in autism is of particular interest to the debate of how influential language is to colour categorisation. Language delay forms part of the diagnostic criteria for autism (DSM-IV, 1994) and deficits in language functioning are commonly observed in individuals with this disorder (De Fossé, Hodge, Makris et al., 2004), these difficulties range from a total absence of functional language to impairments in phonological processing, vocabulary, higher order syntax and semantics (Lord & Paul, 1997; Rapin, 1996; Tager-Flusberg, 2003). In contrast to these language difficulties are reports of enhanced perceptual skills. For example, children with autism have been found to display relatively enhanced performance in detecting embedded figures (Joliffe & Baron-Cohen, 1997; Shah & Frith, 1983), on the Block design test from the Weschler Intelligence Scales (Shah & Frith, 1993), and in copying impossible figures (Mottron Belleville & Ménard, 1999). In a fairly recent study, individuals with autism were found to be more accurate than verbal IQ matched controls in judging the shape of a slanted circle in a context where ambient visual cues are eliminated (Ropar & Mitchell, 2002). It also appeared that controls were influenced by prior knowledge about the stimulus, whereas for the autism group, judgements appear to be more perceptually based.

Participants with low functioning autism (LFA) and high functioning autism (HFA) were compared with participants with typical development (TD) and mild learning difficulties (MLD) on a series of tasks investigating colour naming, colour discrimination, and colour categorisation. If linguistic factors exert more influence on colour processing than perceptual factors, differences between participants with and without autism may be found on tasks where naming appears important (naming, categorisation task). Further, if children with autism show enhanced perception they may consequently show better performance than controls on the perceptual task (experiment six).

EXPERIMENT FIVE - COLOUR NAMING

Background

Reliable colour naming has previously been reported to appear surprisingly late at around four to seven years of age. (Bornstein, 1985; Heider, 1971; Johnson, 1977; Mervis, Catlin & Rosch, 1975). Although young children can name, discriminate and categorise colours appropriately, correct and consistent colour naming develops rather late in comparison to naming in other related and comparable domains (Bornstein, 1985). Many children experience great difficulty in learning their first colour word (Bornstein, 1985b; Soja, 1994). To learn a colour word, children must represent the word, they must represent the colour, and they must make an association between the two. Research has shown that children who do not know which colours, colour words refer to, are nevertheless able to produce colour words (Backsneider & Shatz, 1993; Bartlett, 1977; Binet, 1969; Church, 1961; Cruse, 1977; Istomina, 1963). These difficulties may occur either because the concepts that they need to map with colour words are inadequate or because the process of mapping is difficult. (Soja, 1994).

It is possible that children do not have adequate conceptual representations of colour and that their colour categories are purely perceptual. The idea is that having a perceptual representation of colour (being able to perceive colour) does not guarantee having a conceptual representation of colour (being able to make associations between colours and other things). Soja (1994) proposed the 'conceptual hypothesis' whereby children are unable to acquire colour words until they undergo conceptual development. Thus, according to this theory, acquisition of colour words is dependent upon the output of general learning mechanisms (Bates, Benigni, Bretherton, Camaioni & Volterra, 1979; Bates & MacWhinney, 1982; Bruner, 1975; Greenfield & Smith 1976; Rummelhart & McClelland, 1987).

The second possible explanation for children's difficulty in acquiring a first colour word is that they represent colours conceptually, but are limited in their mappings between words and meanings. This implies that, whilst children cannot map colours onto words, they can map colours onto other things. Many people have argued that children's inferences about the meanings of words are constrained (Clark, 1987; Markman, 1989; Soja, Carey & Spelke, 1991; Waxman & Gelman, 1986). The language acquisition hypothesis (Soja, 1994) proposes that whilst children have the basis for acquiring colour words, they require further development of language-specific mechanisms or knowledge (Chomsky, 1965; Petitto, 1987; Pinker, 1979). This implies that children have innate colour concepts that can be developed through imitation, reinforcement and language development.

Soja (1994) presented a series of experiments that supported the language acquisition hypothesis in showing that children who do not know colour words still have conceptual representations of colour. They were able to map words onto colours and could make inferences about colours. However, despite being able to associate a word as a colour term, they were still unable to refer the word to the actual colour.

It has also been suggested that acquisition of colour terms is constrained by a systematic developmental order of acquisition. Berlin and Kay (1969) proposed that the eleven basic colour terms would appear in a specific temporal order both across languages (an evolutionary hierarchy), and by children within a particular language (a developmental order). There is substantial empirical evidence of up to eleven universal perceptual colour categories (Hardin & Maffi, 1997). Six of these eleven categories are considered to be perceptually unitary or unique. Four unitary hues (red, green, blue, yellow) are unique in appearance and cannot be described in terms of any other colour combinations, and there are also two achromatic colours (black and white). It is believed that these six terms are perceptual building blocks that can be used to describe all colours either by applying them singly or in their various combinations. There is also evidence that these six unitary percepts are mediated at the cortical level by colour opponent processes. However, little is known about the exact physiological mechanisms involved, and it is unclear whether the neural representations of unitary and non-unitary hues are different (Billock, 1997; De Valois & De Valois 1993; DeValois, DeValois, Switkes et al., 1997; Hurvich & Jameson, 1957; Ratliff, 1976).

In general, the six primary colours have been reported to appear first (Boynton & Olson, 1990; Corbett & Davies, 1992; Kay & McDaniel, 1978; Millar & Johnson-Laird, 1976).

They are also named more accurately than non-primary colours (Davis, Corbett, McGurk et al., 1994; Davies & Corbett, 1997; Dougherty, 1978; Istomina, 1963; Johnson, 1977; Cruse, 1977). However, in a recent study, the advantage for naming these primary terms was found not to co-occur with an advantage for comprehending them (Pitchford & Mullen, 2002).

Pitchford and Mullen (2002) found that children acquire accurate knowledge about the first nine basic colours terms (red, yellow, green, blue, black, white, orange, pink, purple) at an earlier period (between 35.6 to 39.5 months) than had previously been shown. However these findings were consistent with those of Shatz, Behrend, Gelman et al., (1996), who showed that three year olds possessed some knowledge of the nine basic colour terms, and two year olds possessed knowledge of four of them (red, yellow, green and blue). Shatz et al., (1996) suggested that children have earlier colour knowledge than children of previous generations because they attend pre-school and are exposed to highly coloured stimuli from an early age. In the study by Pitchford and Mullen (2002), it was shown that children acquire accurate knowledge of the eleven basic colour terms in two distinct time periods. In the first phase, spanning three months, they acquire knowledge of yellow, blue, black, green, white, pink, orange, red and purple (in any order). Then, after a gap of six to nine months they learn about brown and grey, the final two basic colours.

Studies of adult colour naming have shown that conceptual colour space is categorically organised in a manner that reflects the arrangement of perceptual colour space (Boynton & Olson, 1987; 1990; Sturges & Whitfield, 1995; Guest & Van Laar, 2000). It has been shown that children gradually acquire this system of perceptually based conceptual colour categories during the developmental period in which they learn about colour terms (Pitchford & Mullen, 2003). It is proposed that initially the nine colour categories that lie to the outside of perceptual colour space become consistently mapped to the corresponding conceptual representations in any order. The lag in acquisition of reliable knowledge of brown and grey suggests that the internal structure of conceptual colour space becomes consistently mapped at a later point in development.

Aside from brown and grey, the order of acquisition of the other colour terms appears to be unconstrained, and might be shaped by environmental factors specific to any individual child, such as parental input (Andrick & Tager-Flusberg, 1986). This is consistent with other studies that have suggested that adult colour naming is unconstrained (Davidoff, Davies & Roberson, 2000; Roberson, Davies & Davidoff, 2000; Saunders & van Brakel, 1997).

Brown and grey may be acquired later because children have been found to have difficulty with low frequency colour terms, most of which refer to internal non-basic colours that are mentioned rarely in children's books (Braisby & Dockrell, 1999; Corbett & Davies, 1997). Alternatively these colours may be less perceptually salient or lack functional significance (Pitchford & Mullen, 2002). Pitchford and Mullen (2005) recently replicated the finding that brown and grey are acquired relatively late and confirmed that these colour names appear less in child directed speech. They also found a significantly lower preference for these, in comparison to basic colours. However, despite difficulties with the linguistic terms for these colours, the children in the study were able to accurately discriminate them and use them to make perceptual judgements regarding object similarity (Pitchford & Mullen, 2005).

Experiment five will investigate colour term production and comprehension for the eleven basic colours terms in participants with autism and controls. It is hypothesised that as children with autism have atypical language acquisition (De Fossé et al., 2004; Tager-Flusberg, 2003), they will show correspondingly atypical performance on the colour name comprehension and production tasks. As the developmental literature shows that colour comprehension appears before colour naming (Zelazo, Frye & Rapus 1996; Zelazo & Reznick, 1991), such a pattern may also be found in the developmentally delayed participants without autism.

Participants

Thirteen children with HFA aged between 7 years 11 months to 15 years 0 months (mean 10. 9) with non-verbal IQ score between 78-109 (mean 91.17), and thirteen children with LFA aged between 7 years and 2 months to 15 years and 8 months (mean 11.4) with non-verbal IQ ranging between 55-69 (mean 62.15), were matched with children with MLD and TD on age, gender and non-verbal IQ scores using Ravens Matrices (Raven, Court, Raven 1988).

Receptive Vocabulary scores, measured by the BPVS were also obtained and are shown together with other psychometric data overleaf in table 4.1

Table 4.1: Children's psychometric data

Group	Age		Ravens		BPVS	
Autism (26)	**11.2**	**2.53**	**76.31**	**16.87**	**56.12**	**12.23**
HFA (13)	10.9	2.69	91.17	10.75	64.42	9.75
LFA (13)	11.4	2.46	62.15	6.82	47.69	8.41
Controls (26)	**11.2**	**2.25**	**77.58**	**16.42**	**77.00**	**21.63**
TD (13)	10.8	2.45	89.07	13.33	89.00	21.58
MLD (13)	11.5	2.07	65.54	7.73	62.23	10.31

Apparatus

Eleven Colour Aid Matt surface colour squares measuring two inches square and backed with stiff card. The eleven were the best exemplars of focal colours and were the saem stimuli as used by Roberson, Davidoff, Davies et al., (2004). The C*I*E*L*a*b co-ordinates and the hue (H), chroma (C) and saturation (V) for the 11 focal colours were as follows.

	L*	a*	b*	H	V	C
Grey	71.11	0.75	-.61	6.78P	6.95	0.29
White	100	0	0	.46y	9.90	0.00
Brown	44.12	6.06	7.77	3.41YR	4.28	1.70
Orange	81.63	36.51	72.4	3.94yr	8.03	13.85
Purple	39.6	25.81	-21.39	6.228	3.84	7.30
Black	34.71	2.68	2.27	1.14YR	3.38	0.60
Yellow	90.42	8.97	83.5	1.25Y	8.93	12.64
Red	58.82	61.92	43.04	6.66r	5.71	15.70
Blue	49.31	0.92	-48.11	3.66PB	4.78	11.93
Green	57.32	-42.37	-1.97	3.14BG	5.56	8.42
Pink	69.6	51.72	35.63	2.88R	8.75	8.45

The tiles were placed in a random order in front of the children and they were required to name the colours. The procedure was then repeated and this time the experimenter gave the colours names and the children were asked to point to the corresponding colour tile. Responses were written down by the experimenter. The tiles remained on the table throughout both of the tasks.

Results

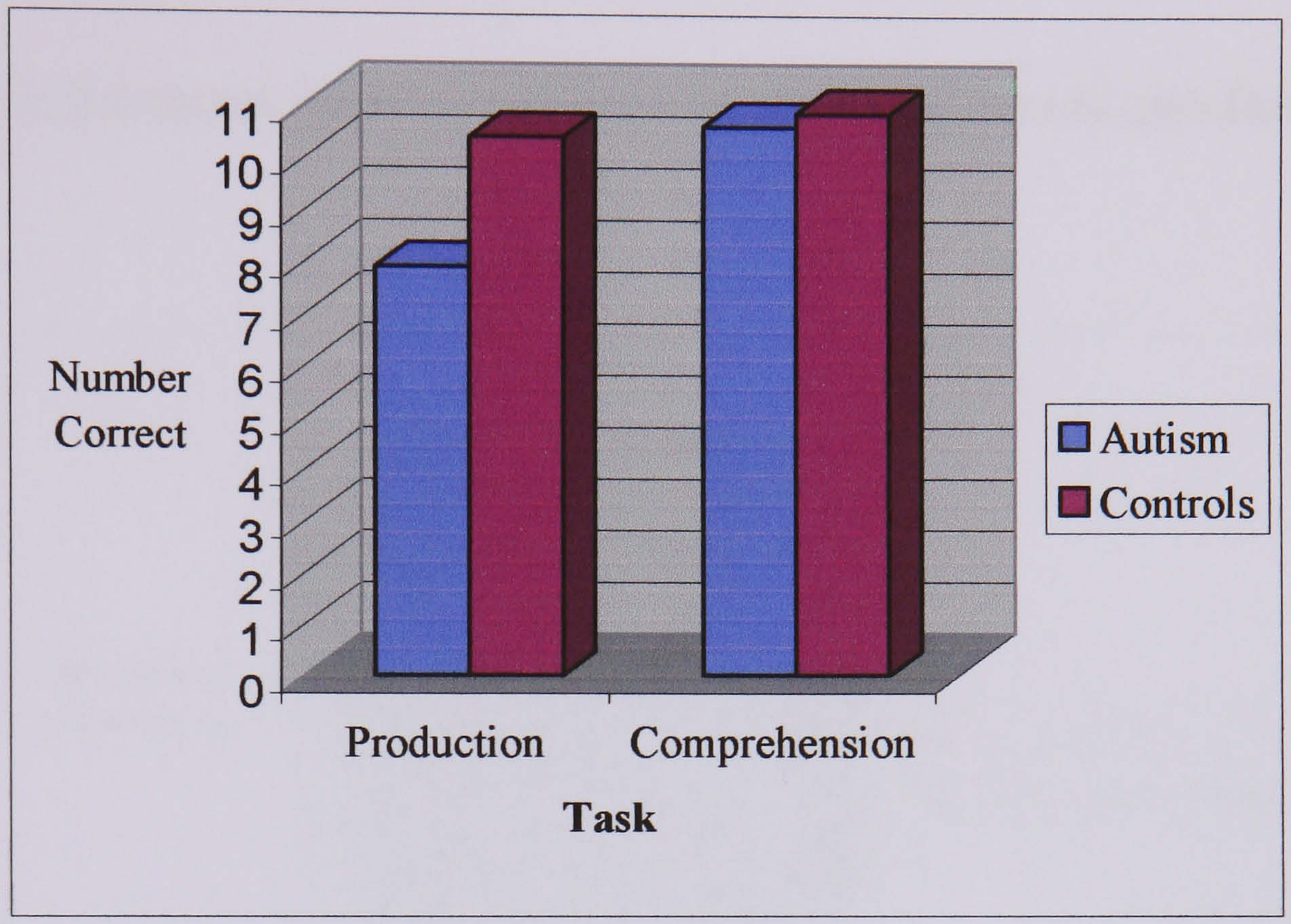
Table 4.2: Mean number correct on the production and comprehension task

Group	Production- naming		Comprehension		Total	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Autism (26)	**7.92**	**4.78**	**10.62**	**1.09**	**18.54**	**5.28**
HFA (13)	11.00	0.00	11.00	0.00	22.00	0.00
LFA (13)	4.85	5.21	10.23	1.48	15.08	5.66
Controls (26)	**10.42**	**2.19**	**10.88**	**0.43**	**21.31**	**2.31**
TD (13)	11.00	0.00	11.00	0.00	22.00	0.00
MLD (13)	9.85	3.05	10.77	0.59	20.62	3.18

* Optimal score 11

An Initial Analysis of Variance was carried out on the data. Group (autism/controls) was the between factor and condition (number correct on the production and comprehension task) as the within group factor. The analysis showed a significant main effect of condition ($F(1,50)=10.36$, $p<.05$) and a significant main effect of group ($F(1,50)$,$=6.06$, $p<.05$). There was also a significant group x condition interaction ($F(1,50)=5.18$, $p<.05$) which is shown in figure 4:1.

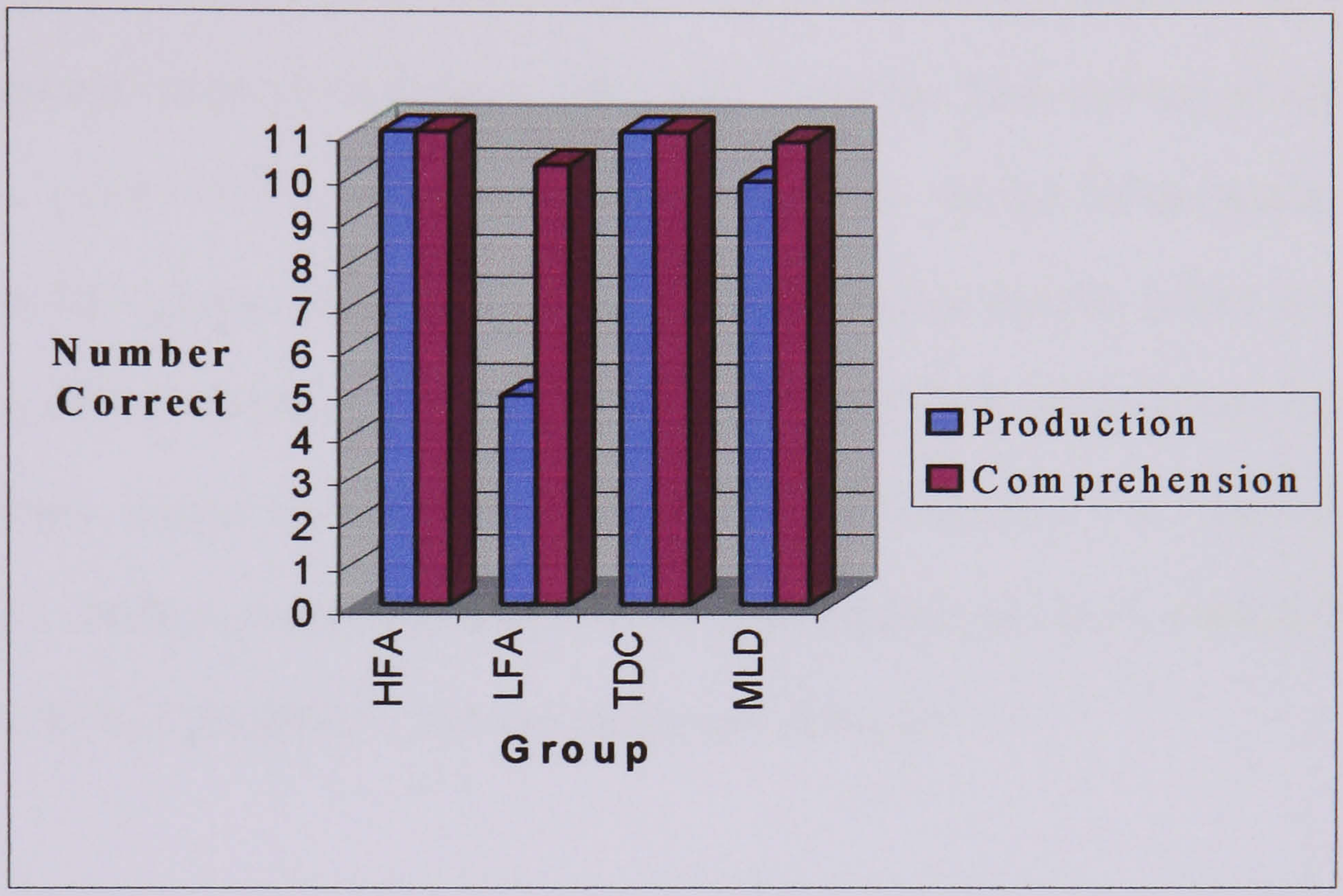
Figure 4.1: Number of colours correctly identified by the group with autism and their controls



Post-hoc t-tests with Bonferroni adjustments were carried out on the interaction. Results showed that the children with autism produced a significantly poorer level of performance on the colour word production condition than controls, ($t(50)=-2.42$, $p<.05$). However, there was no significant difference in colour comprehension between groups ($t(50)=-1.16$, n.s.). Within groups, the children with autism showed significantly poorer colour name production than comprehension, ($t(25)=-3.05$, $p<.05$). There was no significant difference between measures for the control group, ($t(25)=-1.09$, n.s.).

A second analysis of variance was carried out in which the children were subdivided into intellectually impaired (non-verbal IQ<70) and unimpaired (non-verbal IQ>70) groups. This analysis revealed a significant main effect of group, ($F(3,48)=13.39$, $p<0.001$), a significant main effect of condition, ($F(1,48) = 14.43$, $p<.001$) and a significant interaction of group and condition, ($F(3,48)=9.63$, $p<.001$), which is shown in figure 4.2.

Figure 4.2: Number of colours identified correctly for the low and high functioning groups



Post hoc tests with Bonferroni adjustments were carried out. Results revealed no significant differences between the HFA and TD (both groups performed at ceiling). There were also no significant differences between TD and MLD on either the production task, ($t(24)=1.36$, n.s.), or the comprehension task, ($t(24)=.14$, n.s.). There were significant differences between LFA and MLD groups on the production task, ($t(24)=-2.99$, $p<.05$) but not on the comprehension task, ($t(24)=-1.22$, n.s.), between the HFA and MLD groups on the production ($t(24)=2.99$, $p<.05$) but not the comprehension task, ($t(24)=1.22$, n.s.), between the HFA and LFA groups on the production task, ($t(24)=4.26$, $p<.001$) but not on the comprehension task, ($t(24)=1.87$, n.s.), and between the LFA and TD groups on the production ($t(24)=4.26$, $p<.001$), but not on the comprehension task, ($t(24)=1.87$, n.s.).

Within groups there were no significant differences between the scores on the production and comprehension tasks for the children with HFA or TD (all children from both groups scored at ceiling on both tasks). Neither was there a difference across task for the children with MLD ($t(24)=-1.095$, n.s.). Only the LFA showed a significant difference ($t(24)=-3.77$, $p<.05$) with better performance on the comprehension task. Within the LFA group a wide distribution of colour word production scores was noted. Inspection of the individual case data showed that six of these children were unable to name colours, despite ceiling performance on the comprehension task. The remaining seven LFA children performed satisfactorily on the production task, correctly naming more than 80% of the stimuli. This will be further discussed.

As all participants with TD and HFA achieved ceiling scores on both production and comprehension tests, correlations were carried out on the data from the cognitively impaired groups (MLD, LFA) only. For the LFA group production scores did not correlate with scores on the BPVS ($r=.21$, n.s.), Ravens Matrices ($r=.048$,.n.s.) or with Age ($r=-.12$, n.s.). Similarly, comprehension scores did not correlate with scores on the BPVS ($r=.093$, n.s.), Ravens Matrices ($r=.44$, n.s.) or age ($r=-.37$, n.s.). For the participants with MLD, production scores did not correlate with scores on the BPVS ($r=.014$, n.s.), Ravens Matrices ($r=.29$, n.s.) or Age ($r=-.25$, n.s.). There were also no significant correlations between comprehension scores and scores on the BPVS ($r=-.31$, n.s.), Ravens Matrices ($r=-.079$, n.s.) or Age ($r=-.37$, n.s.).

Discussion

Results showed that when comparing the performance of children with autism (high and low functioning) with controls on tasks of colour comprehension and production, deficits in producing colour words were in evidence. However no between-group differences emerged on the comprehension task. Within group analyses showed that children with autism were significantly worse at the production task than the comprehension task, whereas there was no significant difference in performance across the two tasks in the control groups.

When the groups were split into cognitively impaired and unimpaired groups, it was shown that both the HFA and TD groups scored at ceiling on both the production and comprehension tasks. The LFA and MLD groups also performed very well on the comprehension task, although group differences emerged on the production task with poorer performance in the LFA group. It was particularly interesting that a sub-group of the LFA participants performed at near ceiling on the comprehension task despite being unable to name colours. The discrepancy between the comprehension and production tasks is in line with previous findings from typically developing children, showing that they can point to correct colours (comprehend) without being able to name them (Zelazo et al., 1991; Zelazo et al., 1996). Although each of the LFA children without colour naming had an intelligence and age matched MLD control, the matching variable was non-verbal and the mean verbal IQ was lower in the LFA group than in the MLD group. It is also relevant that the verbal IQ test measured receptive rather then productive vocabulary, and the autism sample may have included children with more general speech production difficulties. Indeed inspection of the individual LFA group data showed that the majority of these participants were as able to name colours as their MLD controls.

The analysis of the errors made by the participants with MLD and LFA did provide some evidence for developmental delay in colour comprehension and naming. As previously mentioned, it has been proposed that knowledge about the six primary colours appears first (Boynton & Olson, 1999; Corbett & Davis, 1992; Kay & McDaniel, 1978; Millar & Johnson-Laird, 1976), although Pitchford and Mullen found limited support for a developmental advantage of primary over secondary colours (Pitchford & Mullen, 2005). In the current study, the cognitively impaired children made no production or comprehension errors with red, green, yellow or blue stimuli. These four colours are described as unitary hues, and are believed to be perceptually unique in that they cannot be described in terms of any other colour combinations (Hardin & Maffi, 1997). The only errors on primary colours were for the two achromatic colours, black and white. Difficulties in identifying and naming grey were noted in some of the cognitively impaired children. This finding is consistent with previous research showing late acquisition of this colour (Pitchford & Mullen, 2002; 2003; 2005).

In the next study to be reported, colour discrimination within four primary colours categories will be tested.

EXPERIMENT SIX - COLOUR DISCRIMINATION

Background

Colour discrimination has been shown to develop at an early age and is prevalent even in those who are unable to name colours. Infants can distinguish colour differences within the first few weeks of life (Maurer & Adams, 1987; Teller, 1998; Teller & Bornstein, 1985). For example, infants as young as four months are able to discriminate one colour from another and recognise when two colours are the same (Bornstein, Kessen, & Weiskopf, 1976; Catherwood, Crassini & Freiberg, 1989; 1990). In fact, similarities in hue are one of the earliest criteria used by young children to categorise objects (Melkman, Tversky & Baratz, 1981).

No research has directly investigated colour discrimination ability in children with autism. However, an aspect of this disorder that has aroused considerable interest and is central to the cognitive theories of autism outlined in the introduction, concerns proposed atypicalities in perceptual information processing. If superior discrimination ability, as predicted by the EPF (Mottron & Burack, 2001) and RG theories (Plaisted, 2001) is characteristic in autism, exceptionally high sensitivity thresholds for small differences between colours should be found. Of relevance are findings from studies showing higher discrimination thresholds for differences between pairs of complex tones in autism (Bonnel, Mottron, Peretz et al., 2005; Heaton, Pring & Hemelin, 1999; Heaton, 2003). In the study by Heaton, participants with autism and typical development were asked to make same different discriminations of pairs of complex tones that differed in perceptual distance. The findings showed that whilst participants with autism showed similar levels of performance when perceptual distances were small (between 1 & 4 semitones), medium (between 5 & 8 semitones) or large (between 9 & 12 semitones) controls showed a clear effect of perceptual distance with discrimination performance increasing as perceptual distance increased. The following study will test whether such an effect will generalise to colour discrimination. The hypothesis predicts that discrimination performance will be superior in autism in comparison to controls.

Participants

The children were the same as those who participated in the colour naming task (experiment five).

Stimuli

The stimuli used in the program were derived from Munsell colours (Munsell, 1905). All colours in the present studies were kept at brightness level six and saturation level six. Each of the colours generated was (100*100 pixels) in size.

Apparatus

All experiments were shown on a computer with a monitor. The monitor was placed on a table so that the viewing distance remained approximately equal to 49cm. Experiments were programmed for presentation through purpose-made programs written in E-prime V1.0 (Psychology Software Tools, Inc). Examples of the colours for the four major hue values were chosen from the book, and then converted for the computer into x, y, Y co-ordinates using the Munsell conversion software. Once the x, y, Y co-ordinates had been selected, they were programmed into bit images using the CS100 software (Davies, 2003; purpose written software Goldsmiths College). Colour calibration was achieved as in Roberson and Davidoff (2000) using the CS100 program and was carried out in order to ensure the colours remained comparable across testing sessions.

Procedure

Training Trials

Stimuli: Colours of the following hue 1R, 9R, 10R, 1B, 9B, 10B, 1G, 9G, 10G, 1Y, 9Y, 10Y.

Children were shown three colour patches next to each other 2cm apart. The children were then required to choose the odd one out from the three colour patches. In the training trials the interval between the target colour and the two distracters was larger than in the experimental paradigms. In the testing trials the children saw, for example, 1B (target) with two 9B (distractor) or a 9B (target) with two 1B (distractors). Otherwise they saw 1B (target) with two 10B (distractors) or a 10B (target) with two 1B (distractors). This was the same for red, yellow and green. In the training stimuli distractor patches differed from target patches at intervals of 8.5 or 9. Eight trials (two examples for each colour) were shown. The computer generated colours in a random order. Children completed as many trials as was necessary to reach ceiling performance, and for those had not reached ceiling at the end of the eight training trials the trials were repeated. The stimuli remained on the screen until the children had made a response. Children responded by pointing to one of the colours on the screen and the experimenter recorded the response via the computer. The position of the colours and order of presentation of stimuli were randomised by the computer for each participant.

Experimental Trials:

Stimuli: Colours of the following hue 2.5R, 5R, 7.5R, 10R, 2.5B, 5B, 7.5B, 10B, 2.5G, 5G, 7.5G,10G, 2.5Y, 5Y, 7.5Y, 10Y.

The process was exactly the same as for the training trials. The degree of difference between the target and different distractor patches was varied over experimental trials. There were 24 trials, six of each colour (red, blue, green, and yellow) in small, medium and large conditions. In total, children saw two stimuli of each colour at each interval level. The two small intervals were at a distance of 2.5 hue from the target colour. In this condition children saw either (2.5hue, 2.5hue & 5hue) or (2.5hue, 5hue, 5hue) for each colour (red, blue, green and red). In two, the medium condition, the stimuli were at a distance of 5hue from the target. In this condition they saw either (2.5hue, 2.5hue & 7.5hue) or (2.5hue, 7.5hue, 7.5hue) for each colour (red, blue, green and red). As large interval distances (2.5 &10) within the yellow and red colour categories are not within category exemplars, separate analyses were carried out on these.

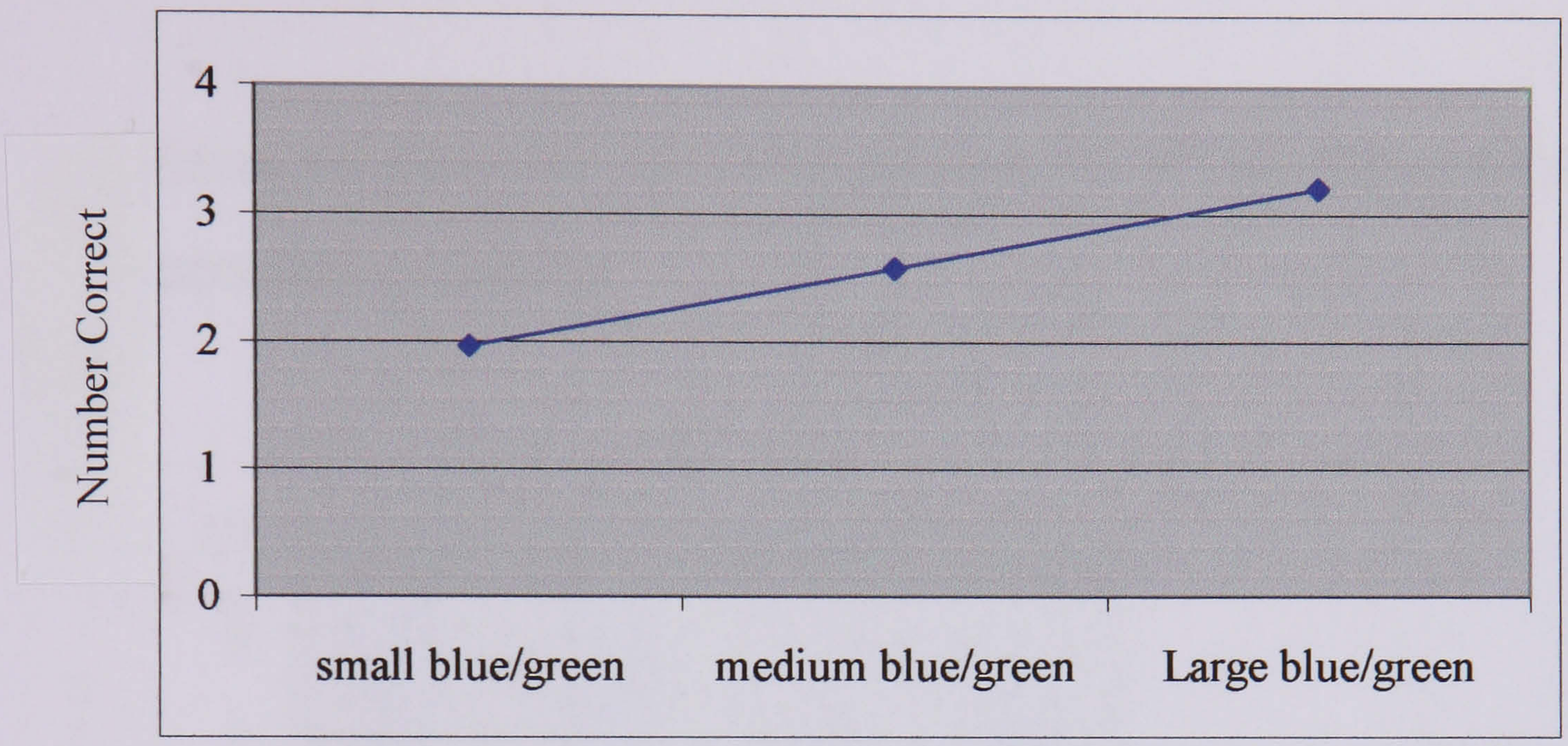
Results.

Table 4.3: Means and SDs for the total number of colours correctly identified in the three experimental conditions (small, medium and large perceptual distances) in the blue and green categories.

Group	Small		Medium		Large	
	Mean	sd	Mean	sd	Mean	sd
Autism (26)	**2.19**	**1.13**	**2.54**	**.98**	**3.08**	**1.09**
HFA (13)	2.54	.96	3.00	.70	3.85	.55
LFA (13)	1.85	1.21	2.08	1.03	2.31	.94
Controls (26)	**1.73**	**1.28**	**2.62**	**.98**	**3.35**	**.84**
TD (13)	2.08	1.25	3.08	.49	3.69	.48
MLD (13)	1.38	1.26	2.15	1.14	3.00	1.00

An initial analysis of variance was carried out on the total number of correct colour discriminations at each size interval in the blue and green categories for the main two groups. Group (autism/controls) was the between factor and condition (number correct on small, medium and large conditions) as the within group factor. The analysis showed no significant main effect of group ($F(1,50)=0.03$, n.s.), a significant main effect of condition, ($F(2, 100)=26.39$, $p<.001$) and no significant group by condition interaction ($F(2,100)=2.42$, n.s.). The significant main effect of condition is shown in figure 4.3,

Figure 4.3: Significant perceptual distance effect within blue and green colour categories.

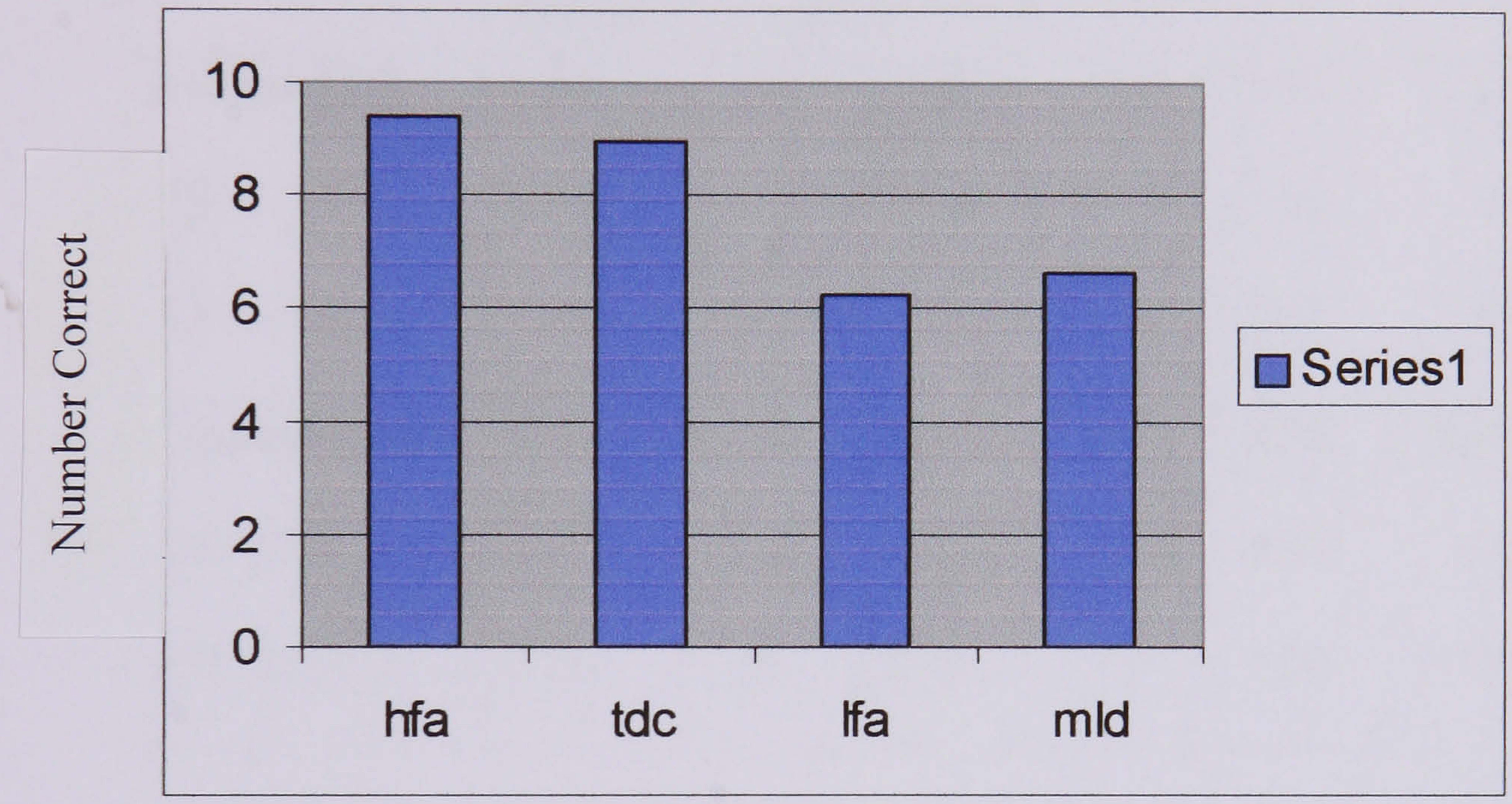


Post hoc tests with Bonferroni adjustments were carried out on the effect of condition. Results revealed significant differences between the small blue/green and the medium blue/green ($t(51)=-3.16$, $p<.05$), between small blue/green and large blue/green ($t(51)=-7.12$, $p<.001$), and also between medium blue/green and large blue/green ($t(51)=-4.22$, $p<.001$).

A second Analysis of Variance was then carried out on the four subgroups (HFA, LFA,TD, MLD). This showed a significant main effect of group ($F(3,48)=8.92$, $p<.001$), a significant main effect of condition, ($F(2,96)=26.26$, $p<.001$) but no significant group x condition interaction, ($F(6,96)=1.39$,n.s.).

As a significant main effect of condition had emerged in the previous comparison of autism (HFA/LFA) and controls (TD/MLD) and no interaction effects emerged when the groups were further subdivided, no further analysis of the condition effect was carried out. Figure 4.4 shows the significant main effect of group.

Figure 4.4: Significant main effect of group for discriminations within blue and green colour categories



Post hoc tests with Bonferroni adjustment were carried out and showed that overall discrimination scores for the participants with HFA and TD did not differ significantly ($t(1) = .46$, n.s.), and this was also true for the LFA and MLD groups ($t(1) = -.38$, n.s.). However, scores for the TD group were significantly higher than scores for the MLD group ($t(1) = 2.30$, $p<.05$) and the LFA group ($t(1) = 2.69$, $p<.05$), and scores for the HFA group were significantly higher than scores those for MLD group ($t(1) = 2.76$, $p<.05$) and the LFA group ($t(1) = 3.15$, $p<.05$).

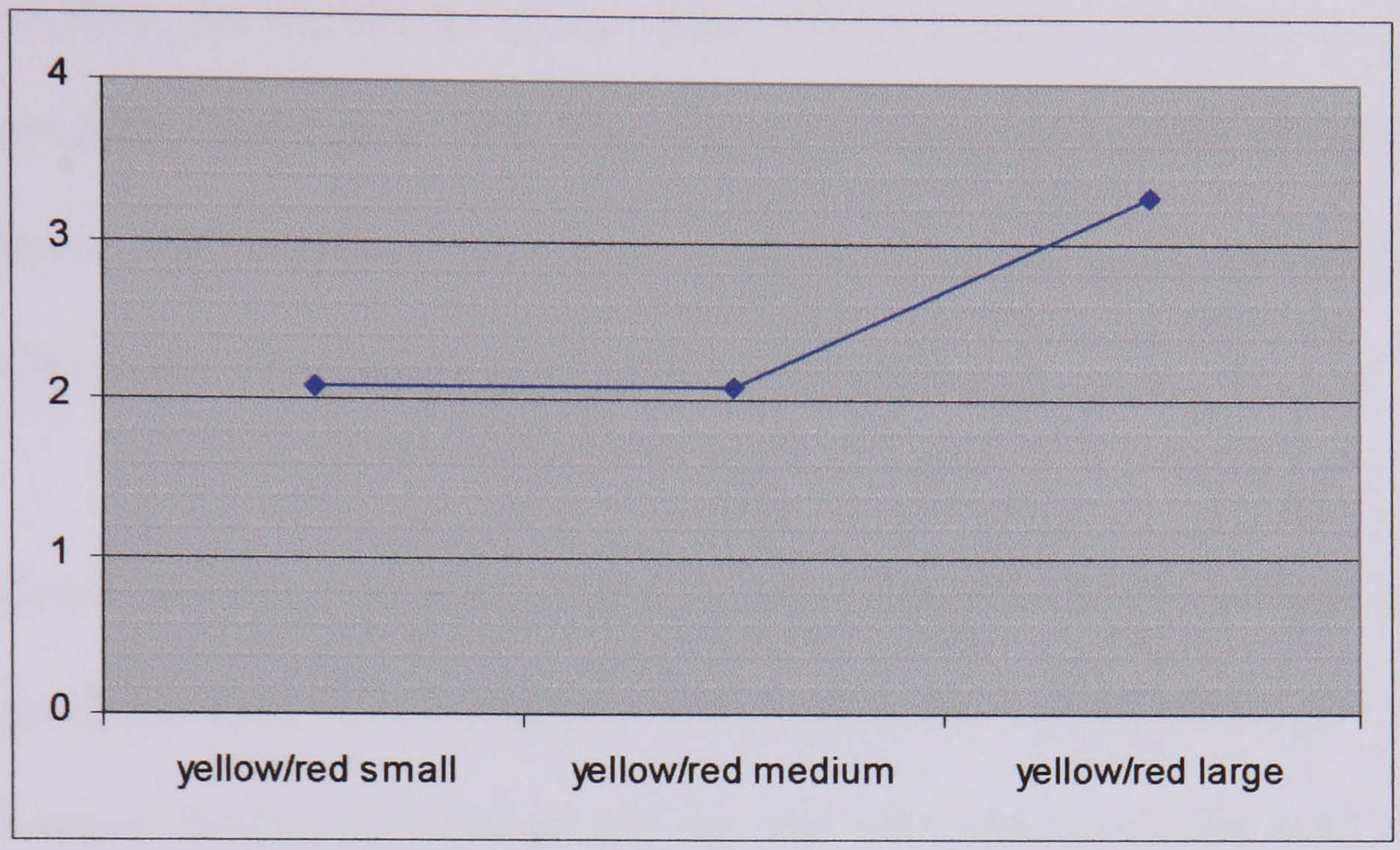
Table 4.4 shows the means and standard deviations for identifications across experimental conditions for yellow and red trials.

Table 4.4: Means and SDs for the total number of colours correctly identified in the three experimental conditions (small, medium and large perceptual distances) in the yellow and red categories

Group	Small		Medium		Large	
	Mean	*sd*	**Mean**	**sd**	**Mean**	**sd**
Autism (26)	**1.88**	**.99**	**1.88**	**.93**	**3.27**	**.82**
HFA (13)	2.08	1.11	2.08	1.11	3.69	.48
LFA (13)	1.69	.85	1.69	.85	2.85	.89
Controls (26)	**2.27**	**1.15**	**2.27**	**1.15**	**3.31**	**1.01**
TD (13)	2.54	1.45	2.54	1.45	3.62	.65
MLD (13)	2.00	.70	2.00	.70	3.00	1.22

An initial analysis of variance was carried out on the total number correct for the colour discrimination at each size interval in the red and yellow categories for the main two groups. Group (autism/controls) was the between factor and condition (number correct on small, medium and large conditions) as the within group factor. The analysis showed no significant main effect of group, ($F(1,50)=1.20$,n.s.) but a significant main effect of condition, ($F(2,100)=62.45$, $p<.001$). There was no significant group by condition interaction ($F(2,100)$,$=1.27$,n.s.). The main effect of condition is shown in figure 4.5.

Figure 4.5: Significant main effect of condition for yellow and red categories in experiment six



Post hoc tests with Bonferroni adjustments revealed significant differences between small yellow/red and large yellow/red ($t(51)=-7.88$, $p<.001$) and between medium yellow/red and large yellow/red ($t(51)=-7.88$, $p<.001$). As shown from figure 4.5, there were no significant differences between small yellow/red and medium yellow/red with groups showing identical mean scores on each.

Also as figure 4.5 indicates, the pattern of performance for yellow and red stimuli is different to that associated with green and blue stimuli. Whilst identifications of small perceptual distances (2.5, 2.5 & 5) within yellow and red were as accurate as identifications of green and blue, increased performance with larger distances (2.5, 2.5 & 7) is not seen with yellow and red stimuli. Performance on the large perceptual distance stimuli that do not remain within colour categories (red and yellow) was much higher.

A second analysis of variance was carried out on the data for the four subgroups (HFA, LFA, TD, MLD). This showed a significant main effect of condition ($F(2,96)=61.38$, $p<.001$), no significant group effect ($F(3,48)=2.25$, n.s), and no significant group x condition interaction ($F(6,96),=.79$, n.s.). Thus, the pattern of performance, showing lower discrimination of medium distance chips and good discrimination of boundary chips, persisted regardless of intellectual status.

Correlations carried out on the data showed that for the autism group, discrimination of green and blue chips correlated with performance on the BPVS ($r = .58$, $p<.01$) and the Ravens Matrices ($r=.68$, $p<.01$) but not with age ($r = -.09$, n.s.). However, for the pooled small and medium red/yellow none of these correlations were significant (BPVS, $r = .46$, n.s.; Raven's matrices, $r = .18$, n.s., Age, $r = .13$, n.s.). Correlations for the discriminations that were not within category (large condition) were significant for Raven's matrices ($r = .50$, $p<01$), for BPVS ($r = .46$, $p<.46$, $p<.04$) but not for age ($r = .05$, n.s.). In comparing scores across the different colour groupings, it was found that discrimination scores for blue/green stimuli did not correlate with discrimination scores for small and medium red/yellow ($r = .29$, n.s.). However, discrimination scores for blue/green stimuli did correlate with discrimination for the large red/yellow (no within category) stimuli ($r = .43$, $p<.05$).

A similar pattern of correlation was found for control participant data. Thus, discrimination of green and blue chips correlated with performance on the BPVS ($r = .59$, $p<.01$) and the Ravens Matrices ($r=.49$, $p<.05$) but not with age ($r = -.109$, n.s.). Data for the pooled red/yellow small and medium distance stimuli also correlated with the BPVS ($r = .73$, $p<.01$) and the Ravens Matrices ($r=.46$, $p<.05$) but not with age ($r = .03$,ns.). Correlations for the discriminations that were not within category (large condition) were not significant for Raven's matrices ($r = .37$, n.s.) or age ($r = -.16$, n.s.), but they were significant for BPVS ($r = .40$, $p<.05$). As was the case for the autism data, discrimination scores for blue/green stimuli correlated with discrimination for the large red/yellow (no within category) stimuli ($r = .62$, $p<.01$), and for this group they also correlated with discrimination scores for small and medium red/yellow stimuli ($r = .50$, $p<.01$).

Discussion

The analysis of the data from experiment six revealed an interesting pattern of findings. When comparing discrimination ability within blue and green ranges across groups (TD, HFA, MLD and LFA), cognitive level appeared to exert an effect. Both the MLD and LFA groups made fewer correct discriminations than the HFA and TD groups.

The pattern of discrimination in response to red and yellow stimuli was very different to that of blue and green, and this was true for all participants regardless of diagnostic or intellectual status. No perceptual distance effect characterised responding across small and medium conditions, although large stimuli that bordered or crossed category boundaries were easily detected. This finding will be further explored in this chapter.

The pattern of correlations between the test scores and psychometric measures was interesting. Unsurprisingly, these showed that the children with the highest verbal and non-verbal scores from all groups, regardless of age, showed best discrimination of blue/green stimuli. However, a different pattern emerged on the yellow/red stimuli condition. For both groups, neither of the intelligence measures correlated with discrimination of small and medium red/yellow pairs, although significant correlations between scores for the large (category boundary) discriminations and the two intelligence measures were significant for the autism group. For controls only the verbal intelligence measure correlated with these scores. Finally, whilst there was a significant correlation between discrimination performance across the green/blue and red/yellow (within category) conditions in controls, this was not found in the autism group. For both groups, discrimination of blue/green stimuli correlated with discrimination of large (category boundary) red/yellow stimuli.

One question that this experiment attempted to address was whether children with autism possess enhanced perceptual discrimination. The statistical analysis of the data failed to support this hypothesis, and the significant group effect reflected differences in intellectual rather than diagnostic status. The issue of atypical perceptual performance in autism will be further discussed.

EXPERIMENTS SEVEN AND EIGHT - COLOUR CATEGORISATION

Background

The emergence of categorisation in early childhood is usually considered in terms of the development of cognitive abilities that permit relations (i.e. similarities or dissimilarities) among stimuli to be detected and represented (Piaget, 1977). However, the propensity to categorise objects by hue may owe its origins more to perceptual than cognitive processes (Bornstein, 1984). For example, similarities in hue are one of the earliest criteria used by young children to categorise objects (Melkman, Tversky & Baratz, 1981).

Bornstein and Korda (1984;1985) and Boynton, Fargo, Olson et al., (1989) showed that categorical effects of hue judgements that parallel those found in judgements of acoustic similarity within and between phonemic categories. Within category 'different' responses are slower than comparable between category 'different' responses. Thus it takes longer to decide that two blue stimuli are different than to decide that a blue stimulus is different to a green stimulus, even when the difference between the two is matched in the number of Munsell hue steps (Bornstein & Korda, 1984).

As outlined in the introduction to this chapter, Categorical perception (CP) may be universal or could co-vary with the distribution of linguistic category boundaries. There are a number of studies with adults that have highlighted effects of language on colour categorisation (Kay & Kempton, 1984; Pilling, Wiggett, Özgen et al., 2003; Roberson, Davies & Davidoff, 2000). For example, Roberson et al., (2000) found substantial differences in perceptual judgements and memory performance between a language with eleven basic colour terms (English) and one with only five basic colour terms (Berinmo), suggesting that language effects memory performance and the perceived similarity of stimuli. This finding was in line with results previously reported by Kay and Kempton (1984).

However, some researchers believe that categorical perception is an innate, universal and perceptual effect. Indeed some studies have shown CP in children as young as four months (Bornstein et al., 1976; Catherwood et al., 1989; Franklin, Clifford, Williamson et al., 2005). Franklin et al., (2005) have also recently published data showing that CP was no stronger in children with developed colour term knowledge than those without this knowledge.

Few studies have directly assessed category formation of children with autism to form categories. However some of these studies of the few that have been carried out have found intact categorisation. For example, Ungerer and Sigman (1987) tested a group of participants with LFA with a mental age range of one to three years, and found that they were able to distinguish between simple perceptual categories, defined by colour and form, as well as between members of natural and artifact categories. In another study, Tager-Flusberg (1985b) found no differences in the meaning attributed to super-ordinate (animal) and basic category labels (cat) between a group of LFA and two control groups. However, the findings from several studies suggest that people with autism do show abnormal responses to categorical information. For example, Dunn, Vaughan, Kreuzer et al., (1999), presented a semantic classification task to children with HFA and controls, and measured ERP responses to words presented auditorally. Whilst the ERP measures of the controls suggested that they had activated mental representations of the super-ordinate category label, the HFA group failed to show these activation patterns. Shulman, Yirmiya & Greenbaum (1995) administered a range of categorisation tests to three groups of children (LFA, TD and learning disabilities). Autism-specific deficits were revealed in a free sorting task in which LFA children made fewer accurate classifications of representative objects. LFA children have also been shown to fail to aid free recall memory by grouping exemplar information into categories (Hermelin & O'Connor, 1970; Minshew, Goldstein, Muenz & Payton, 1992; Tager-Flusberg, 1991), an effect that has also been replicated in adults with autism spectrum disorders (Bowler, Matthew & Gardiner, 1997; Bowler, Gardiner, Grice et al., 2000).

There has also been limited research exploring the prototypicality effect in autism. A prototype can be defined as the most representative member of a category, and a prototype effect can be demonstrated using a categorisation task where an unstudied prototype is classified with equal or greater accuracy than previously studied but less typical exemplars (Metcalfe & Fisher, 1986; Posner & Keele, 1968). Another characteristic of the prototype effect is that recognition levels tend to reflect the degree of similarity between exemplars with very similar prototypes being associated with greater recognition (Cabeza, Bruce, Kato et al., 1999; Omohundro, 1981). Dunn, Gomes & Sebastian, (1996) examined prototypicality in naturally occurring categories using a word fluency task where the children had to list examples of animals and vehicles. The HFA children were found to produce a lower proportion of prototypical responses than either of the control groups (one with language impairment and other with TD). Klinger and Dawson (2001) examined responses to prototypes of artificial categories presented in the form of cartoon animals in children with LFA, Down syndrome (DS) and TD. The TD participants tended to select the prototype whereas both the clinical groups performed at chance levels on the task.

There are two main accounts of categorisation performance in autism. The first proposes that there is an impairment in prototype formation (Klinger & Dawson, 2001), and the second proposes that category deficits are a result of an impairment in processing features held in common between stimuli (Plaisted & O'Riordan & Baron-Cohen, 1998). These accounts, together with the weak central coherence theory (Frith 1989, Frith & Happé 1994), imply a reduced or absent prototype effect in autism (cited in Molesworth, Bowler & Hampton, 2005).

Klinger & Dawson (2001) have argued that prototype formation requires the ability to integrate information across experience to form a central gestalt representation, and therefore any impairment may be a result of wider problems in central coherence. However, the generalisation theory (Plaisted et al., 1998; Plaisted, 2001) predicts that children with autism show enhanced discrimination ability which contributes to the production of sharper category boundaries with narrower category content than is seen in typically developing individuals. If categories have sharper boundaries, then it is less likely that novel unusual exemplars (ie those that might lie at the category boundary for the developmentally normal individuals) will be recognised and encoded as part of an existing category. Plaisted (2001) suggest that this explains why children with autism develop highly restricted interests such that a child with autism becomes fascinated with only a certain make of car.

A recent study carried out by Molesworth, Bowler and Hampton (2005) failed to find impaired prototype effects in autism. In these studies, children with autism spectrum disorder were compared to age and verbal mental age matched controls on a picture recognition task (experiment one) and two prototype recognition tasks. Experiment one required the children to sort pictures of animals and vehicles into category piles before being shown test pictures where half were replicas of the cards just sorted and the remainder novel items. Children had to say whether they had seen the cards before. Experiment two used stimuli of an average prototype structure based on stimuli previously developed by Younger (1985). Here children were shown pictures of cartoon animals that were organised around average prototypes. These prototypes possessed features (legs, noses) that were category average in size. Experiment three used a model prototype structure based on stimuli developed by Hayes and Taplin (1993). These stimuli possessed the feature types that occurred most frequently in the study sets. Such feature types varied in identity such that a head feature could be square or circular. Following study phases, the children were required to complete recognition tests comprising prototypes and other exemplars with varying degrees of similarity to the prototypes. Both groups showed intact recognition memory and a full prototype effect in recognition memory. Thus these results contradicted and failed to support both Klinger and Dawson's (2001) prototype formation theory and Plaisted et al.'s (1998) deficit in common feature processing theory,

The role of perceptual discrimination in category formation is controversial. Notman, Sowden & Özgen (2005) found enhanced sensitivity at the category boundary in a same/different discrimination task. Here human participants were taught to distinguish between two categories of Gabor patterns that differed by spatial phase. Notman et al.

argued that the findings from the study showed that category learning had changed perceptual sensitivity. However, Fahle (2002; 2004; in press) pointed out several flaws in this argument, one of which was that the sensitivity shown in the Notman et al. study failed to generalise to changes in the orientation of the stimuli. Another criticism was that such a narrow bandwidth is an improbable basis for perceptual categorisation since humans would need to learn to categorise the same stimuli separately at many different orientations. Cross-species research has also failed to support any link between enhanced discrimination and narrow boundary categorisation ability. Goldstein, Davidoff and Fagot (submitted) investigated colour discrimination in humans and baboons. Comparisons between humans and the species of baboon (Papiopapio) are justifiable as these primates have been shown to have the same retinal colour vision as humans (Adams, Bryan & Jones, 1968). Before testing Baboons, Goldstein et al., firstly confirmed the human colour category boundary between green and blue via a colour naming task. They then presented the baboons and the human participants with a fixed choice task that contrasted two different cross category and two different within category decisions. The findings from the fixed choice task showed that the boundary position promoted superior recognition in a cross-category task in humans, but not baboons. However, despite the category advantage for humans, psychophysically determined colour discrimination thresholds were very similar for the two species. Therefore whilst humans showed superior categorisation ability at the boundary position, enhanced discrimination was not in evidence. The fact that the two species differ in regards to verbal skills combined with the absence of superior discrimination skills emphasised the role of linguistic factors.

The following two experiments attempted to determine whether children with autism posses similar category boundaries to controls. In experiment seven, participants were required to verbally label Munsell chips from the blue/green range as blue, green or neither, and chips from the blue/purple range as blue, purple or neither. In experiment eight, participants were required to choose the odd one out from three Munsell chips in three conditions. In condition one, chips were all within categories, in condition two there were two within category chips and one category boundary chip, and in condition three there were two within category chips and one chip from a different category.

It was predicted that if children with autism identify the same stimuli as being representative of category boundaries to age and intelligence matched controls in experiment seven, similar levels of performance in experiment eight (the odd one out task) would suggest that they were using a direct language strategy. However, if as suggested by theoretical accounts of autism outlined in the introduction (RPF & RG theories), they are more reliant on a perceptual strategy, they would show different performance to controls across the two tasks. In order to be consistent with predictions drawn from the generalisation theory, children with autism would differ from controls in showing sharper categories boundaries than controls.

EXPERIMENT SEVEN - COLOUR CATEGORISATION (NAMING)

Participants

Twenty children with autism aged between 8 years 0 months to 15 years 10 months (mean 11 years 7 months) with non-verbal IQ scores ranging between 54-109 (mean 82.53) were matched with children with moderate learning difficulties and typical development for age, gender and non-verbal IQ using Ravens Matrices. The Children's Psychometric data is shown in Table 4.5.

Table 4.5: Means and standard deviations for age, Ravens and BPVS participant scores.

	Age		Ravens		BPVS	
Group	**Mean**	**sd**	**Mean**	**sd**	**Mean**	**sd**
Autism (20)	**11.7**	**2.46**	**82.53**	**15.15**	**60.47**	**12.45**
HFA (14)	12.2	2.69	91.71	11.21	63.62	9.77
LFA (6)	11.2	2.31	65.33	6.12	53.67	15.73
Controls (20)	**11.8**	**2.10**	**80.11**	**15.77**	**81.63**	**20.93**
TD (14)	12.0	2.04	86.79	13.18	89.36	21.11
MLD (6)	11.9	1.73	64.17	3.97	66.33	4.84

Stimuli: Stimuli used were from the Munsell collection. The stimulus set for the green-blue range (BG) included Munsell chips, 7.5G, 10G, 2.5BG, 5BG, 7.5BG, 10BG, 2.5B, 5B and 7.5B, all at levels of lightness (4) and saturation (8). The stimulus set crossing the blue-purple boundary (PB) included Munsell chips 10B, 2.5PB, 5PB, 7.5PB, 10PB, 2.5P, 5P, 7.5P and 10P, all at the same lightness and saturation as the blue/green range. All stimuli were mounted on squares of card measuring two inches square.

Method

Children were shown the Munsell chips individually and in a random order. They were asked to choose the colour name they thought appropriate for each of the colour chips.

For the blue/green range they were given the choice of responses of blue, green or neither (not blue or green). For the blue/purple range they were given the choice of blue, purple or neither (not blue or purple). Each chip was removed from sight immediately after naming.

Figure 4.6: The colour names given to the Munsell chips by the participants with autism

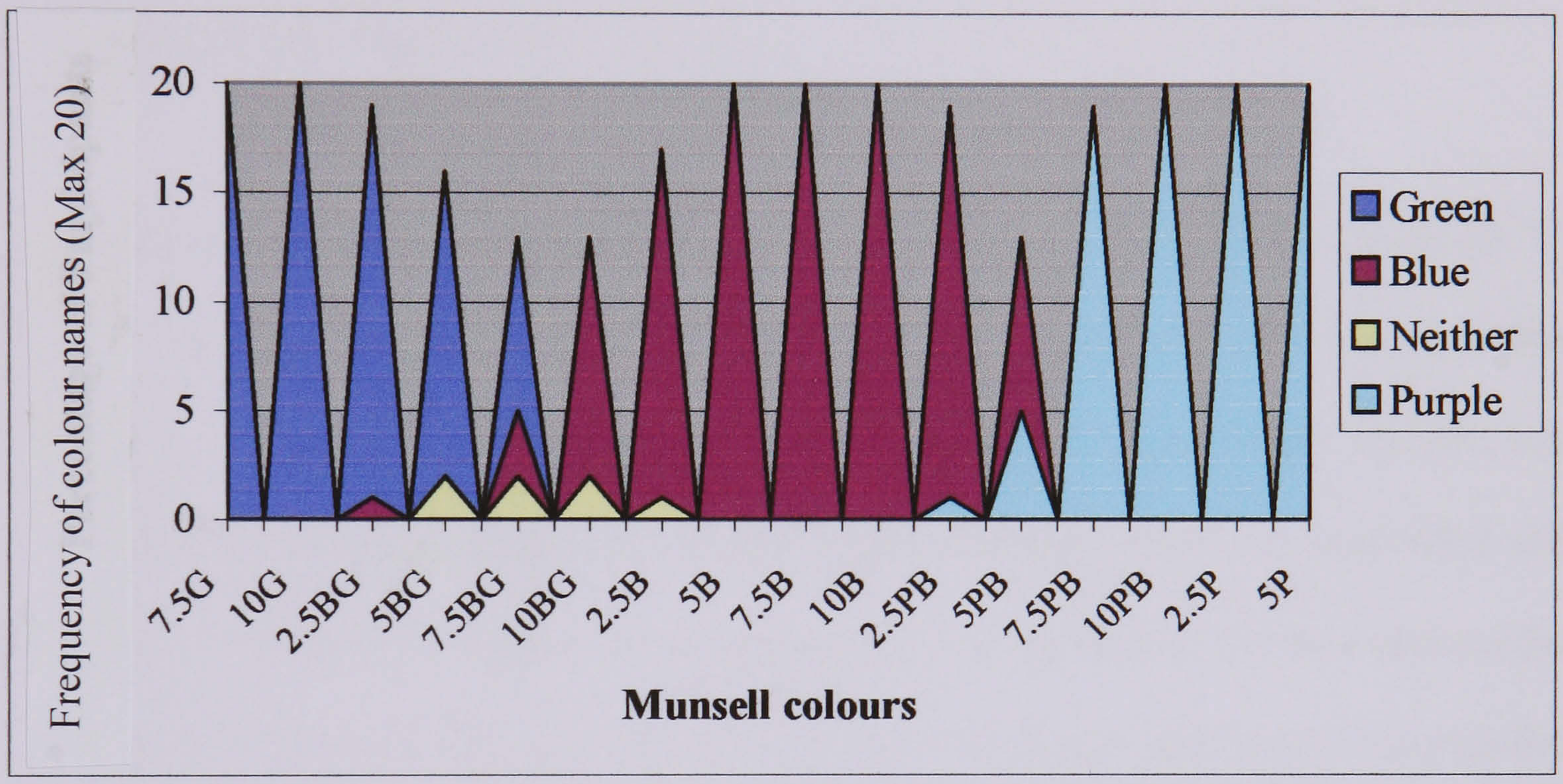
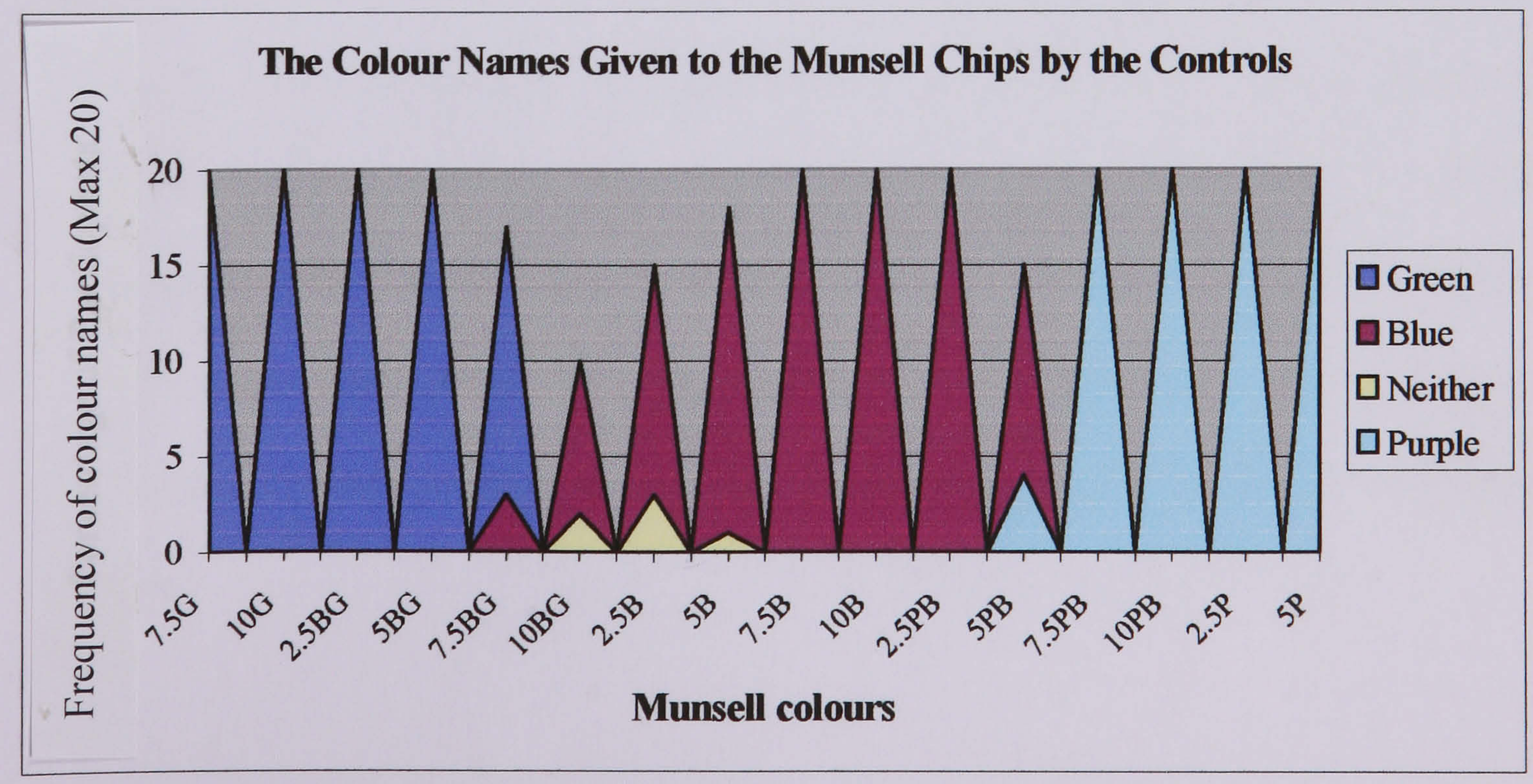


Figure 4.7: The colour names given to the Munsell chips by the controls



Figures 4.6 and 4.7 show the frequency of the responses for the control group and the group with autism. It appears that for both groups, the blue/green boundary is around 5BG and 7.5BG with the majority of children calling 5BG green and 7.5BG blue. For the blue/purple range the boundary was around 5PB and 7.5PB, with the majority of children calling 5PB blue and 7.5PB purple. There was more variation across the category boundaries for the children with autism, and they appeared to show lower levels of consensus on the colour name for 7.5BG, 10BG, 2.5B (blue/green range) and 5PB (blue/purple range) chips.

For analysis purposes, colour chip/name pairs that were most frequently selected by TD control participants were considered to be correct. Fisher's exact tests were then carried out comparing the number of children with autism and their controls who labelled chips with the correct colour name or gave another choice (i.e. responded with the other colour name or gave a neither response). The analysis of the data showed that for the 5BG chip the difference between children with autism and controls approached statistical significance ($p<.053$). There was no significant difference for 7.5BG ($p<0.14$), 10BG ($p<0.26$), 2.5B ($p<0.35$), 2.5PB ($p<0.50$) or 5PB ($p<0.35$). It thus appeared that the children with autism showed similar performance to controls in naming across the blue/purple boundary. Whilst the differences in naming across the green/blue boundary were not statistically significant, it did nevertheless warrant further investigation. Whilst controls clearly found the Munsell chip 5BG to be best represented by the colour name green, the children with autism were less consistent in this assessment and their category boundary for the BG range appeared to be wider than controls.

EXPERIMENT EIGHT - COLOUR CATEGORISATION (TRIAD TASK)

Procedure

In the second categorisation experiment, children were asked to identify the chip that appeared to be the most different in a triad of three similarly coloured chips. Again, chips were drawn from the BG range and PB ranges. On the basis of the findings from experiment seven it was predicted that, when participants were required to identify the odd one across category manipulations, differences between groups would again be seen across the BG and PB ranges.

Stimuli

The chips were the same as those used in experiment seven. They were 7.5G, 10G, 2.5BG, 5BG, 7.5BG, 10BG, 2.5B, 5B and 5P for the blue/purple range and 5B, 7.5B, 10B, 2.5PB, 5PB, 7.5PB, 10PB, 2.5P and 5P for the blue/purple range. All stimuli used had lightness (value) 4 and saturation (chroma) 8. The exact specifications for the triads (1-16) are provided in the appendix.

Method

Training trials: The children were shown pictures of irregular objects (see appendix) in triads of three, where two were similar (either in size, colour or shape) and one was very different. The triads were placed one at a time in front of the children and they had to choose the one that was most different. The children were told if they were correct or not and given an explanation for the correct answer. The triad was then replaced with another one. Training continued until participants correctly labelled three triads in a row.

Experimental Trials

The triads of stimuli contained either (1) three chips within a category (5B, 2.5B and 10BG) (triads 1,2, 7, 8); (2) two chips within a category and one boundary chip (2.5B, 10BG, and 7.5BG - eg 2.5B, 10BG, 7.5BG); triads 3, 4, 5, 6, 9, 10, 14, 16); or (3) two chips within a category and one from other category (e.g 5B, 10BG, 5BG; see triads 11, 12, 13, 14). Chips were either one, two or three steps apart, but always with equal spacing between the adjacent pairs of the triad. As was the case in the training trials, the children were asked to choose which of three chips was the most different. Each triad was placed in front of the participant in random order. Once the children had responded, the chips were removed and replaced with another triad.

Results

Children received a total score out of sixteen. For the three chips within category they received a score of one if they chose the chip nearest the next category boundary as most different. Where there were two chips within category and one boundary chip, they scored one if they chose the boundary chip as most different. For the triads that included two chips within and one across category, they scored one for choosing the across category chip as most different. Means and standard deviations are shown below in table 4.6.

Table 4.6: Mean and standard deviations on the scores (chose the predicted chip) in blue/green range, blue/purple range and the combined total.

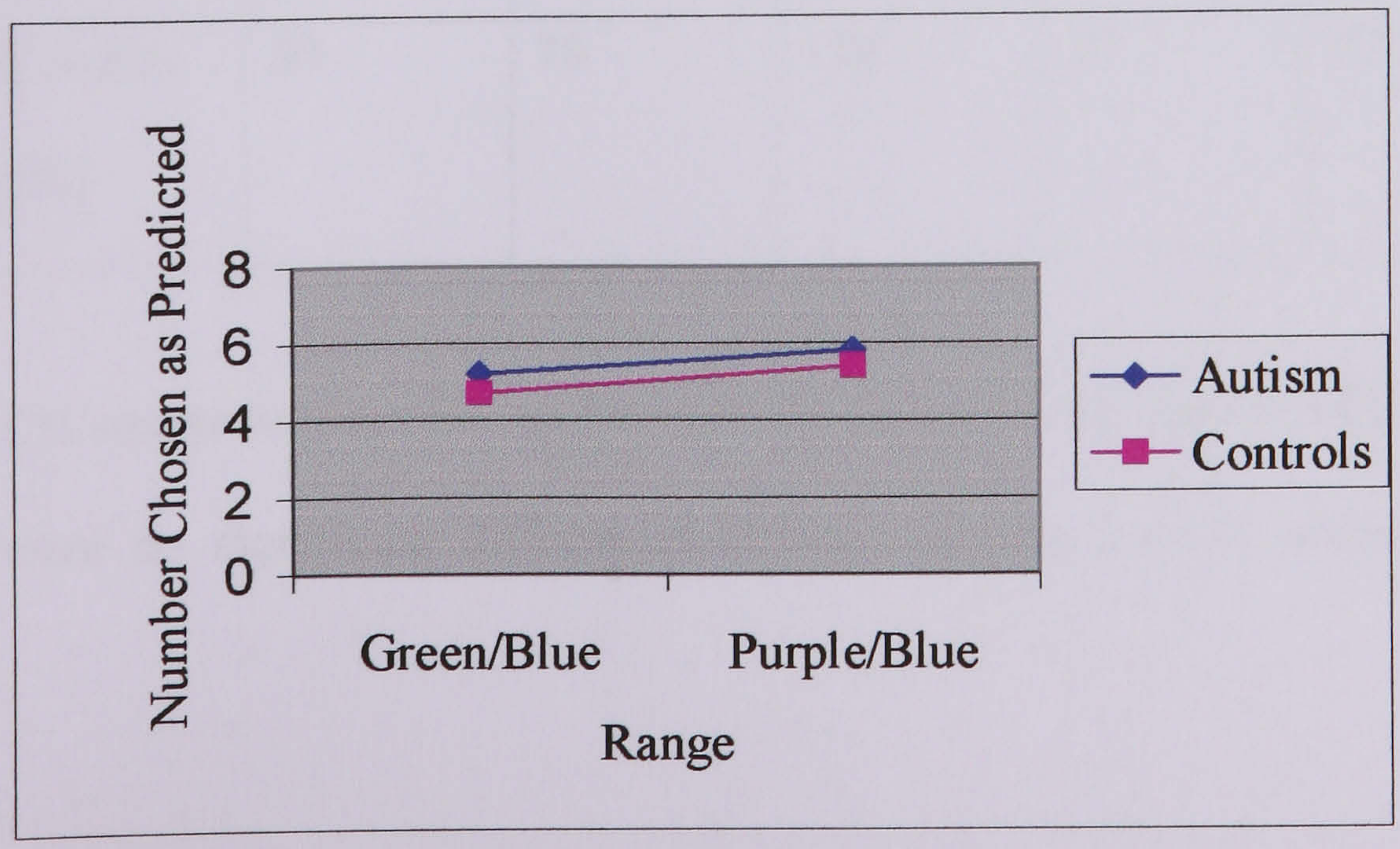
Group	Total Score		Blue/Green		Blue/Purple	
	Mean	sd	Mean	sd	Mean	sd
Autism (20)	11.20	2.20	5.20	1.28	5.80	1.44
Controls (20)	10.10	1.65	4.70	1.26	5.40	0.88

*Optimal total score=16, Optimal score for Blue/Green and Blue/Purple range=8

An Analysis of variance revealed a significant main effect of condition, ($F(1,38)=7.55$, $p<.05$). However there was no significant main effect of group, ($F(1,38)=2.11$, n.s.), and no significant group by condition interaction, ($F(1,38)=.045$, n.s.).

Post-hoc analysis of the significant main effect of condition showed that participants from both groups performed as predicted across the blue/purple range significantly more often than across the blue/green Range, ($t(39)=-2.78$, $p<.05$). This is shown in figure 4.8.

Figure 4.8: Scores across the blue/green range and the blue/purple range



In the next analysis the number of predicted chip choices across the three conditions (e.g. all within, 2 within + boundary chip, 2 within + 1 different category chip), was calculated. The maximum frequency for each triad was 20 (number of children from each group). This meant that for the all within condition, where there was four different triads (4x20), the optimal choice frequency was 80. This was the same for the 2 within + 1 different category condition. For the 2 within + 1 boundary chip there were eight triads (8x20), so the optimal score was 160.

Table 4.7 shows the choice frequency for the predicted chip and the other two chips across conditions.

Table 4.7 Frequency of predicted and non-predicted chip choice across the three conditions

Group	All Within Optimal score=80		2Within +Boundary Optimal score=160		2With + Category Optimal score=80	
	Predicted	Other	Predicted	other	Predicted	Other
Autism (20)	54	26	124	36	55	25
Controls (20)	50	30	118	42	52	28

Chi square was carried out between the groups in the three conditions separately. There were no significant differences between groups for the within condition (χ^2= .44;

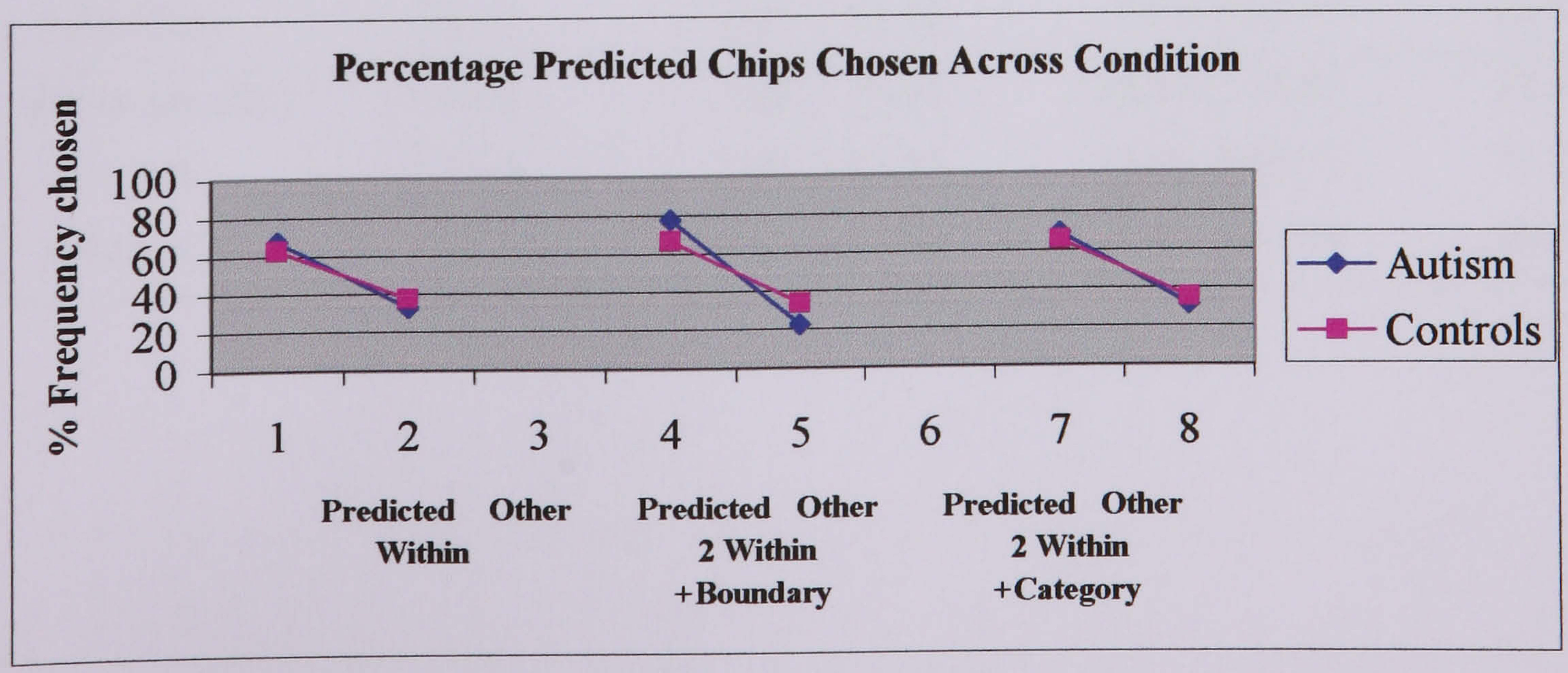
df=1,p=.51), the 2 within +1 different category condition (χ^2= 0.25; df=1, p=.61) or the 2 within + 1 boundary condition (χ^2= .61; df=1, p=.44).

The percentage of predicted or unpredicted chip choice is shown overleaf in table 4.8 and illustrated in figure 4.8. As can be seen from figure 4.9, the two different participant groups showed very similar levels and patterns of performance.

Table 4.8: Mean percentage of choices for the predicted and unpredicted chips across the three conditions

Group	All Within		2Within +Boundary		2With + Category	
	Predicted	Other	Predicted	other	Predicted	Other
Autism (20)	67.50	32.50	77.50	22.50	68.75	31.25
Controls (20)	62.50	37.50	73.75	26.25	65	35

Figure 4.9: Percentage predicted chips chosen across conditions



As the RG theory proposes that generalisation abnormalities in autism reflect atypical perceptual processing, and the findings from experiment six had showed a significant effect of cognitive impairment on discrimination of blue and green, separate analyses were carried out in which the autism and control groups were subdivided into intellectually impaired and unimpaired groups.. In order to maintain group sizes, data from a further six children with LFA and their MLD controls was included. Although the LFA participants had been able to comprehend colour names, some were unable to produce them (see experiment five) and had therefore been excluded from experiment seven. However, they had been able to complete experiment eight and they were reintroduced into the subject sample. The details for all who participated in experiment eight are shown in table 4.9 below.

Participants

Table 4.9: Means and standard deviations for age, Raven and BPVS for the low and high functioning groups

Group	Age		Ravens		BPVS	
	Mean	sd	Mean	sd	Mean	sd
Autism (26)	**12.2**	**2.58**	**76.19**	**17.07**	**56.61**	**13.43**
HFA (13)	11.9	2.58	90.46	10.60	64.53	9.34
LFA (13)	12.5	2.65	61.92	7.29	54.69	12.33
Controls (26)	**12.1**	**2.28**	**75.15**	**16.15**	**75.85**	**21.38**
TD (13)	11.8	2.45	87.46	13.46	88.69	21.82
MLD (13)	12.5	2.15	62.85	5.81	63.00	10.89

The scoring system was the same as shown for experiment six. Table 4.10 shows the means and standard deviations for predicted chip choice in blue/green range, blue/purple range and the combined total.

Table 4.10 Means and standard deviations for predicted chip choice in the blue/green range, the blue/purple range and the combined total.

	Total Score		Blue/Green		Blue/Purple	
	Mean	**sd**	**Mean**	**sd**	**Mean**	**sd**
Autism (26)	**10.08**	**2.79**	**4.77**	**1.48**	**5.31**	**1.74**
HFA (13)	12.00	1.58	5.69	1.03	6.31	1.25
LFA (13)	8.15	2.38	3.85	1.28	4.31	1.60
Controls (26)	**9.73**	**1.95**	**4.31**	**1.43**	**5.42**	**0.99**
TD (13)	10.08	1.32	4.54	0.97	5.54	0.97
MLD (13)	9.38	2.43	4.08	1.80	5.31	1.03

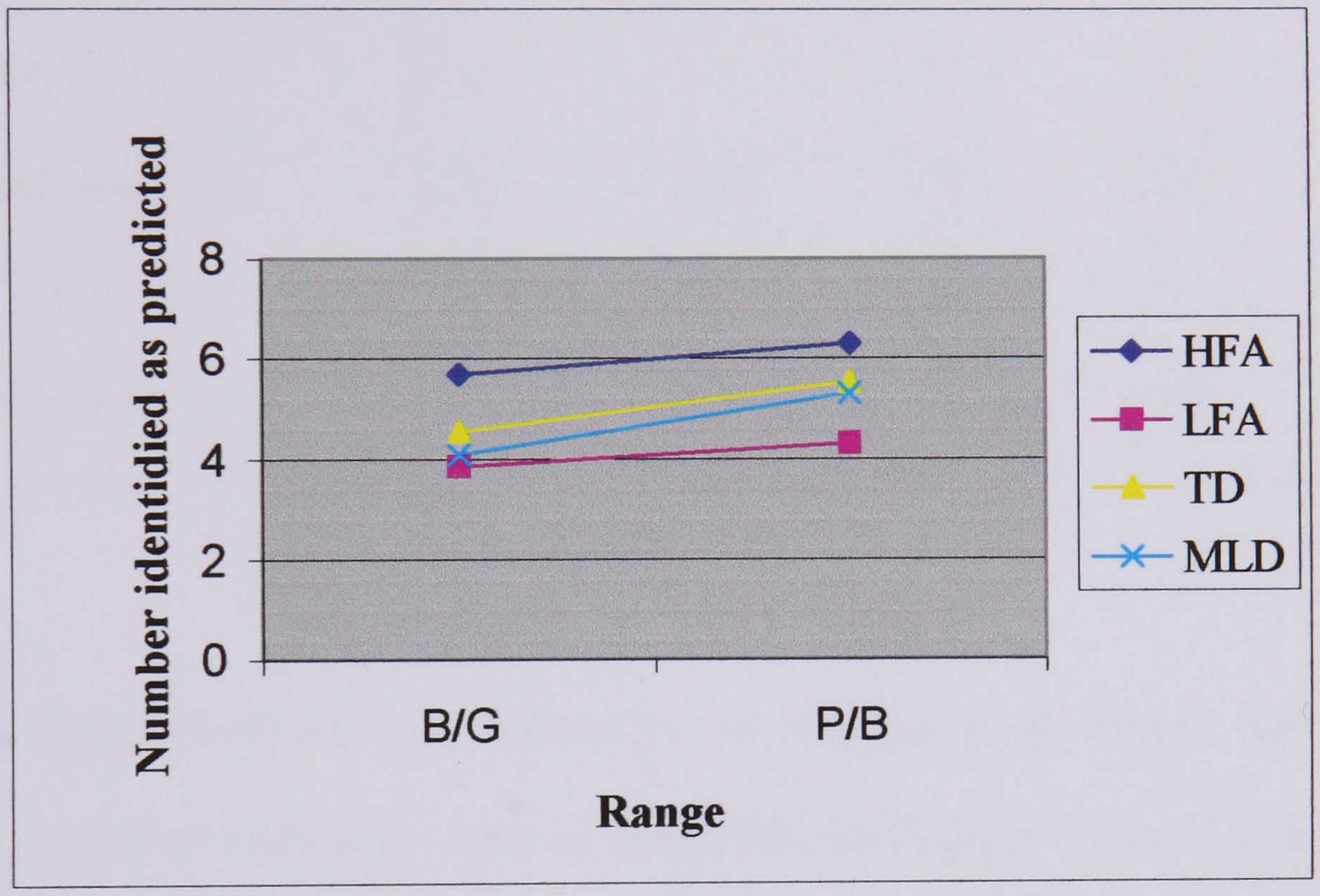
* Optimal score 16

An analysis of variance was then carried out on the data from the subdivided groups (HFA, LFA, MLD, TD). This revealed a significant main effect of condition, ($F(1,48)=13.92$, $p<.001$); and a significant main effect of group, ($F(3,48)=8.50$, $p=.001$). However there was no significant group by condition interaction, ($F(3,48)=.630$, n.s.).

As can be seen from table 4.10 and figure 4.10 below, all participants performed as predicted for the PB range more often than for the BG range. Independent t-tests with Bonferroni adjustments were carried out on total scores for groups (BG and PB range).

These revealed a significant difference between the HFA and TD, (t(24)=3.37, p<.05); between HFA and MLD, (t(24)=3.25, p<.05); and between the HFA and LFA, (t(24)=4.86, p<.001). There were no significant differences between TD and MLD, (t(24)=.90, n.s.); between TD and LFA, (t(24)=2.55, n.s.); or between LFA and MLD, (t(24)=-1.31, n.s.).

<u>**Figure 4.10: Scores for the blue/green range and blue/purple range**</u>



The percentages of predicted and unpredicted chip choices are shown overleaf in table 4.11. .

Table 4.11: Percentages of choices for the predicted and unpreducted chips across the experimental conditions

Group	All Within Optimal Score =80 Predicted	Other	2 Within + Boundary Optimal Score =160 Predicted	Other	2 Within +Category Optimal Score =80 Predicted	Other
Autism	**67**	**37**	**131**	77	**65**	**39**
HFA (13)	37	15	84	20	36	16
LFA (13)	30	22	47	57	29	23
Controls	**64**	**40**	**129**	**79**	**65**	**39**
TD (13)	35	17	68	36	31	21
MLD (13)	29	23	61	43	34	18

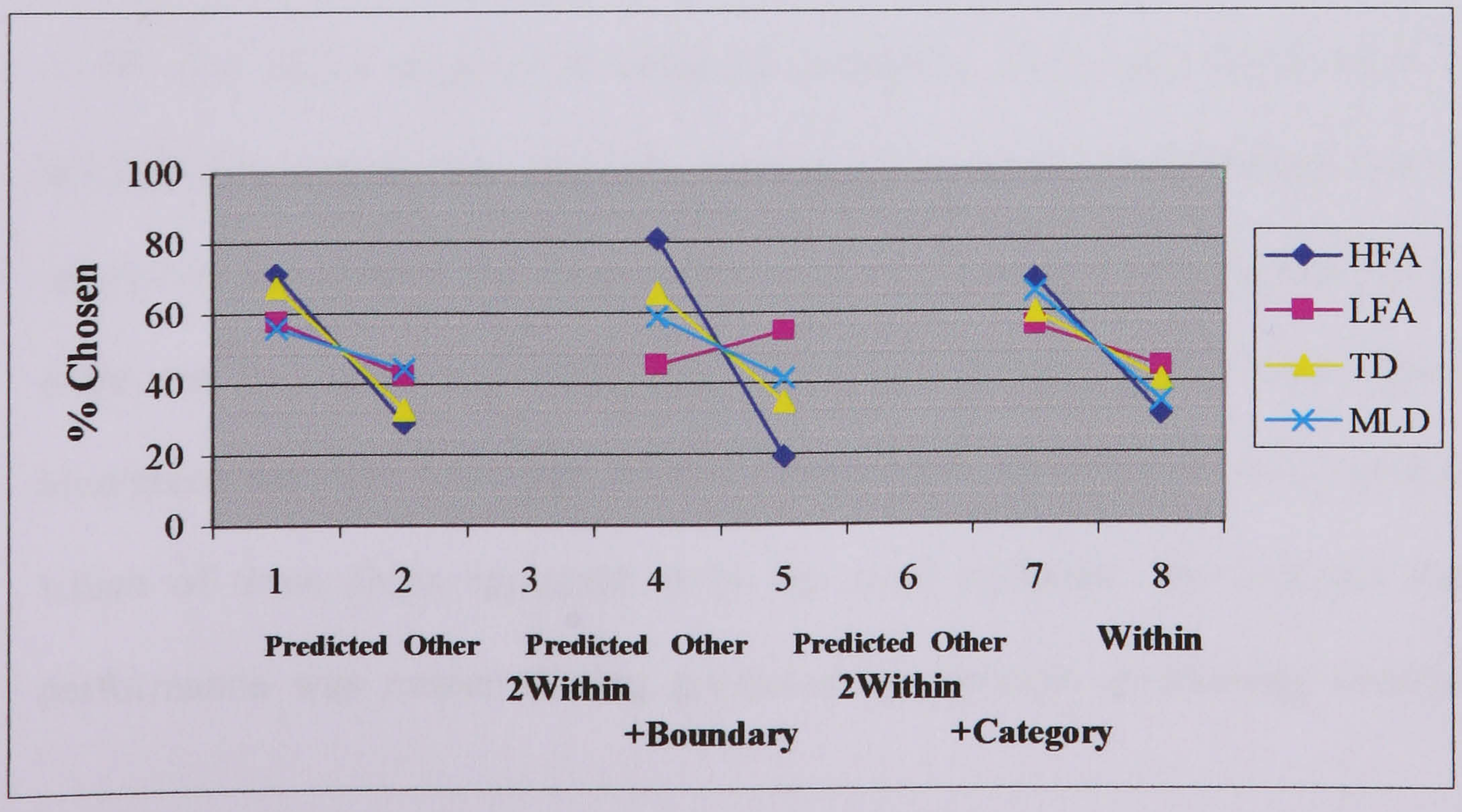
Chi square analyses were carried out on between group data in the three conditions. These showed that there were no significant differences between groups for the within condition (χ^2= 3.69; df=3, p=.29) or the 2 within +1 different category (χ^2= 2.38; df=3, p=.49). However there was a significant difference for the 2 within + 1 boundary condition (χ^2= 29.13; df=3, p<.001. Further analysis for the 2 within + 1 boundary condition revealed significant differences between, HFA and LFA (χ^2= 28.23; df=1, p<.001), HFA and TD (χ^2= 6.26; df=1, p=.012), HFA and MLD (χ^2= 12.04; df=1, p<.001), TD and LFA (χ^2= 8.58; df=1, p=.003), LFA and MLD (χ^2= 3.78; df=1, p=.05). However, no significant differences were found between the TD and MLD (χ^2= 1.00; df=1, p=.32).

The percentage of predicted or unpredicted chips chosen is shown in table 4.12 and illustrated in figure 4.11.

Table 4.12 Mean percentage of predicted and unpredicted chips chosen across the three conditions

Group	Within		2 Within +Boundary		2 Within +Category	
	Predicted	**Other**	**Predicted**	**Other**	**Predicted**	**Other**
Autism	**64.42**	**35.58**	**62.98**	**37.08**	**62.50**	**37.50**
HFA	71.15	28.85	80.77	19.23	69.23	30.77
LFA	57.69	42.31	45.19	54.81	55.76	44.24
Controls	**61.54**	**38.46**	**62.02**	**37.98**	**62.50**	**37.50**
TD	67.31	32.69	65.38	34.62	59.62	40.38
MLD	55.77	44.23	58.65	41.35	65.38	34.62

Figure 4.11: Percentage predicted chip chosen across conditions



As can be seen, the autism groups (HF & LF) performed similarly to their matched control groups (TD & MLD) on the within and across category boundary conditions. However the results from the condition that included a boundary chip showed a different pattern. As the chi-square analyses showed, the HFA group gave significantly more predicted responses than the other three groups, and the LFA gave significantly fewer predicted responses than the other three groups.

Correlations were carried out on the data and showed that number correct as predicted did not correlate with age for any of the participants groups (HFA, $r=.09$, n.s.; LFA, $r=.02$, n.s.; TD, $r=-.09$, n.s., MLD, $r=-.20$,n.s.), and this was also the case for Raven's Matrices (HFA, $r = .31$, n.s.; LFA, $r = .001$, n.s.; TD, $r = -.27$, n.s.; MLD, $r = .28$, n.s.) and BPVS (HFA, $r = .24$, n.s.; LFA, $r=.09$, n.s.; TD, $r=-.18$, n.s.; MLD, $r = -.21$, n.s).

Discussion

Experiments seven and eight investigated colour categorisation in autism, MLD and TD. In experiment seven, participants were presented with chips to be named as blue, green or neither or blue, purple or neither. The spectrum for the chips ranged from 7.5G to 5P, and chips selected as category boundary chips were those most commonly labelled this way by the typically developing controls. The findings from the study suggested that, whilst the blue/purple category boundary was similar for all groups, there was less consensus within the autism group about which chip represented the blue/green category boundary. In experiment eight, participants were asked to identify which of three chips appeared to be the most different. The analysis showed that performance was nearer to that predicted by typically developing control data for blue/purple than for blue/green chips. Whilst the initial data analysis did not appear to show differences between the autism and control groups on the different experimental conditions, significant effects for both group and condition did emerge when the subsequent analysis separated groups on the basis of diagnosis and intellectual status. Post-hoc analyses showed that the groups did not differ on the condition where chips were all within category or the condition where one chip was in a different category. However, on the condition that included a category boundary chip group differences did emerge. Whilst there was no significant difference between the TD and MLD groups, the high and low functioning participants with autism performed differently to each other and to their two matched control groups. Further analysis of this effect showed that the HFA participants possessed tighter category boundaries than the other three groups, and LFA participants possessed looser category boundaries than the other three groups. The significance of these findings for theoretical accounts of autism and of colour perception will be discussed in the following section.

GENERAL DISCUSSION

The findings from experiment five showed that children with autism and intellectual impairment possessed good colour name comprehension. Significant differences between groups emerged on the colour naming condition, but this effect depended upon a sub-group of low-functioning children with autism who may have possessed general productive language difficulties. Whilst the HFA and TD groups performed at ceiling on comprehending and naming conditions, some cognitively impaired participants did make some errors on black, white and grey stimuli. Pitchford and Mullen (2002, 2005) had shown that grey is the last colour to appear in typically developing children and this may explain relative difficulties with this colour in developmentally delayed children. However, the cognitively impaired children's overall levels of performance were good and did not provide evidence for deficits in colour comprehension or production. In experiment six (colour discrimination), both the children with autism and controls showed a different pattern of performance across the blue and green categories compared to the red and yellow categories. For the blue and green categories the odd one out chip at each of the intervals, small (2-5,2-5,5), medium (2-5,2-5,7-5) and large (2-5,2-5,10) were within colour categories. Here the cognitively impaired children, both with and without autism, showed a significantly lower level of discrimination performance in comparison to cognitively unimpaired controls with and without autism. The pattern of discrimination performance within the red and yellow categories, where the target (odd one out) chip was within category for the small and medium interval but in another category or at the category boundary for the large interval, was very different to that seen for blue and green categories. Here there was no significant effect of group, and all participants showed a similar pattern of performance across the three size intervals with equally good discrimination in small and medium conditions, and dramatically increased discrimination on the large (boundary) interval condition. For all participants, discrimination of blue/green intervals correlated with performance on the verbal and non-verbal measures, and this was also true for all the stimuli in the yellow/red condition for controls. For participants with autism, only discrimination of the large (boundary) interval in the yellow/red conditions correlated with these measures. For controls, discrimination of blue/green intervals correlated with discrimination of all yellow/red intervals, but for participants with autism only the correlation between blue/green discriminations and large (boundary) yellow/red discriminations was significant. No performance measures correlated with age for either group.

Experiments seven and eight attempted to determine whether category boundaries in autism would differ from those without this disorder. The findings from experiment seven, where children were required to name chips, appeared to show that there was lower consensus about the position of blue/green and blue/purple boundaries for participants with autism. However, only the difference in green/blue boundary choice approached statistical significance. This effect was further investigated in experiment eight. In this experiment, participants were presented with triads of chips and the task was to identify which of them was the least similar to the other two. One condition included three chips that were all within category, and here no group differences emerged. This was also the case for a second condition in which the least different chip was drawn from a different category. However, on the condition that included a boundary chip group differences did emerge. The analysis showed that the performance of the participants with MLD did not differ from that of the TD children. However, the performance of the autism groups (HF & LF) was different to that of their age and intelligence matched controls and to each other. The children with HFA were more likely to respond to criteria chips as to a category boundary, and the LFA children were less likely to do so. This then provided evidence for tighter category boundaries in HFA and looser category boundaries in LFA.

The theoretical accounts of colour processing outlined in the introductory chapter laid stress on the importance of perceptual or linguistic factors. As the theories of autism previously discussed propose that the disorder is characterised by enhanced perception, studies of colour with autism were potentially fruitful in developing both theories on autism and of colour perception. In particular, predictions drawn from the EPP and RG theories would be that individuals with autism would have enhanced perceptual processing (EPF and RG) and narrow category boundaries (RG). However, the findings from experiment six provide no evidence that individuals with autism possess enhanced perceptual processing. Whilst there was clear evidence for atypical colour categorisation in autism, the data from the LFA group was in the opposite direction to that predicted by the RG theory. Although the HFA participants did show tighter category boundaries than controls, they did not show any evidence of enhanced perceptual processing of colour in experiment six. As high acuity perceptual processing and narrow category boundaries are causally linked in the RG model, these findings pose a strong challenge to this account.

In the experimental studies reported in this chapter, participants with autism were individually matched to controls on a measure of non-verbal intelligence and also on chronological age. The findings from studies five and six show that this method of matching can result in groups that show highly comparable performance. However, many of the participants with autism possessed poorer verbal than non-verbal skills than their controls. As outlined in the introduction, delayed language acquisition is a diagnostic criteria for autism, and even able individuals who eventually develop good mechanical language skills (see introduction) show atypical linguistic processing, tending, for example, towards over-literal or concrete language. The linguistic relativity theory predicts that categorical perception varies with language (Kay & Kempton, 1984; Roberson et al., 2000), and it is therefore plausible to suggest that rigid boundary formation, seen in able individuals with autism, reflects these language peculiarities.

When cognitive impairment curtails language development more severely, the role of language in shaping perceptual categories may be negligible and boundaries may be far less well defined. The findings from the current studies lend support to this suggestion. In the following chapter, the relative contributions of perceptual factors and verbal labelling to colour memory will be investigated.

CHAPTER FIVE

INVESTIGATING THE EFFECTS OF COLOUR NAMING ON COLOUR MEMORY IN CHILDREN WITH AUTISM

Summary: In the studies reported in this chapter, children with autism and their age and intelligence matched controls were tested for their ability to remember colours and colour names. In experiment nine, children were presented with animals and colour patches in a paired learning paradigm. It was hypothesised that children who used verbal labels for the presented colours would perform at higher levels on the task. The method used in experiment ten was the same as that used in experiment nine, in that children were exposed to animals and colour patches for pairing. However, in this study four exemplars of the colours to which the children had been exposed were presented in the test phase, and performance could not be facilitated by verbal rehearsal of the animal-colour pairing. In experiment eleven, animals were paired with colour words. Success on this study therefore depended entirely on the children's memory for the verbal labels. Taken together the findings showed that cognitively unimpaired children with autism as well as children with typical development and moderate learning difficulties showed better memory performance in the experiments that allowed the use of verbal labels. In contrast, cognitively impaired children with autism showed their highest levels of performance on the experiment where verbal labels did not facilitate performance.

INTRODUCTION

In the previous chapter, where data from a range of colour experiments was presented, two important findings emerged. The first of these was that children with autism did not show enhanced colour discrimination, and the second was that they appeared to possess different colour category boundaries to their age and intelligence matched controls. As both the Enhanced Perceptual Functioning (EPF) theory and the Reduced Generalisation (RG) theory predict heightened perceptual discrimination, and the RG theory proposes that this results in narrow category boundaries, these theories were rejected in favour of an account that relates abnormal language in autism to categorical perception. In the studies presented in this chapter, the role of verbal labelling in colour memory was investigated.

COLOUR AND MEMORY

Baddeley (1986), and Baddeley and Hitch (1974) outlined a model of memory that specifies a separation of functions for the processing of verbal material (the phonological loop) and visuospatial material (visuospatial sketchpad). The phonological loop is defined as a limited capacity store to which spoken words gain direct access, and includes an articulatory rehearsal mechanism that allows words to be maintained in the store by a process of sub-vocal rehearsal. This articulatory rehearsal mechanism can facilitate memory for visual material by translating written words or pictures into verbal codes, known as phonological/verbal recoding (Laws, 2002).

Developmental research suggests that between the ages of five and eight years children's memory strategies change. Initially they have no particular strategy for remembering pictures, then visual encoding occurs to be followed by both visual and verbal encoding. Finally, they reach a stage where more efficient verbal encoding becomes the preferred strategy (Palmer, 2000). It has been proposed that visual encoding dominates until around seven years, at which point verbal encoding of picture material is established (Brown, 1977; Hayes & Schulze, 1977; Hitch, Halliday, Dodd et al., 1989; Hitch, Woodin & Baker, 1989). However, some studies have shown that children as young as four years are able to use verbal strategies to aid memory (Henry, Turner, Smith et al., 2000; Hitch, Halliday, Schaafsal et al., 1988; Hulme, 1987).

Colour tasks involving memory components are proposed to be particularly susceptible to direct language strategies (Kay & Kempton, 1984; Pilling, Wiggert, Özgen et al., 2003; Roberson & Davidoff, 2000). Berlin and Kay (1969) found that individuals from many different countries chose the same areas of the colour space (from an array of Munsell chips) when asked to indicate the best examples of the colour terms in their language. These most salient areas of colour space are referred to as focal colours (Heider, 1972). The four primary chromatic focal areas (red, blue, green and yellow) are proposed to be the most memorable colours (DeValois & Jacobs, 1968; Heider, 1972). Heider (1972) found that focal colours were recognised more accurately by English and Dani speakers and were named more rapidly by speakers of these languages. Studies carried out with children have shown that they are more likely to select and are better able to match (Heider, 1971), comprehend, and name focal colours than non-focal colours (Andrick & Tager-Flusberg, 1986). Non-focal colours take a significantly longer time to name and may attract a variety of non-basic and basic terms. For example, a colour near the category boundary between green and yellow might be correctly called green, yellow, lime or chartreuse (Laws, 2002).

Memory for individual colours is related to how easily they can be verbally labelled (Brown & Lenneberg, 1954; Lantz & Stefflre, 1964). For this reason it has been argued that remembering focal colours is easier, as a verbal coding strategy can be used for the task (Davidoff & Ostergaard, 1984; Garro 1986; Lucy & Schweder, 1979; Ridley, 1987). An advantage of verbal coding is that labelled target colour can be retained and aid recognition (Pilling & Davies, 2004). Krauss (1968) showed this to be particularly advantageous under conditions of delayed recall. However Heider (1971;1972) and Rosch (1973) pointed out that focal regions possess perceptual cognitive distinctiveness, and suggested that perceptual salience rather than codeability may determine how well colours are remembered (Pilling & Davies, 2004). It has been suggested that the memory advantage for focal colours may only occur on certain types of memory tasks. For example, Lucy and Shweder (1979) used a task in which focal and non-focal colours appeared equally distinctive and found significant differences for long-term but not for short-term memory.

Cross-cultural research also suggests that there is a processing advantage for focal over non-focal colours (Roberson, Davidoff, Davies et al., 2004). In a longitudinal memory study, Himba speaking children, whose language includes five basic colour terms, were compared to English speaking children whose language includes eleven basic colour terms. If colour categories are universal, innate and independent of language, then the prediction was that both the Himba and English children who knew no colour-terms would share the same set of categories (eleven BCT). Both populations would also be predicted to demonstrate similar confusions in memory, because colours belonging to the same category should appear more alike than those from different categories. The results from the study showed that when children were unable to produce any colour terms there was no memory advantage for focal terms in either language. For the children with no colour term knowledge, the pattern of memory performance for both the Himba and English speaking groups was very similar and appeared to be based on perceptual distance rather than a specific set of categories. However an advantage for the focal colours became evident in both languages once the children had begun to acquire colour terms. Of those children knowing at least one colour term at the first time of testing, English children showed superior memory performance for the items that were focal to only English and to those focal to both English and Himba categories The Himba children also showed superior recognition for those items that were focal in Himba and in both Himba and English categories.

Of particular relevance to the question of how language impacts on colour memory are studies comparing the performance of individuals with known language deficits to those with typical development. Laws (2002) carried out such a study with a group of children with Down syndrome. Memory investigations into Down syndrome have revealed a selective impairment of the phonological loop component of working memory (Jarrold & Baddeley, 1997). The phonological loop has been implicated in language acquisition (Baddeley et al., 1998; Gathercole & Baddeley, 1993), and such a deficit would clearly impact on language development in Down syndrome (Chapman, 1995; Fowler, 1995; Laws 1998; 2002). Indeed, deficits in expressive language in children and adults with Down syndrome have been described (Gibson, 1978; Chapman 1995; Miller, 1987).

In Laws's (2002) study, children with Down syndrome were presented with focal colour stimuli (typical examples of English basic colour categories) and non-focal colour stimuli (those that form category boundary regions with intermediate names) in two experimental conditions. It was argued that if children use a verbal coding strategy, focal colours should be recalled more successfully than non-focal colours that are less easily named. As a visual processing advantage is believed to be characteristic in Down syndrome (Buckley & Bird, 1993; Freeman & Hodapp, 2000), it was predicted that the children with Down syndrome would show superior visual memory and perform better than controls in the non-focal colour condition. Several experimental studies have also shown a visual memory advantage in children with Down Syndrome. In one experiment contrasting auditory digit span and memory for printed digits, Broadley, MacDonald & Buckley (1995) reported that printed digits resulted in significantly better performance than that achieved with auditory stimuli alone. Memory training studies have also shown a significant advantage for picture memory over serial recall of words (Broadley & MacDonald, 1993; Comblain, 1994; Laws, MacDonald & Buckley, 1996). As the phonological processing deficit in Down syndrome was predicted to decrease the likelihood of them adopting a verbal coding strategy, they were predicted to perform less well on the focal colour condition than normal controls without a phonological processing deficit.

As predicted, typical controls remembered the focal colours at significantly higher levels than the children with Down syndrome, but both groups performed at similar levels in the non-focal colour memory condition. Therefore, whilst the results failed to support superior visual memory in Down syndrome, they did show that their poor phonological coding impacted on their memory for focal colours

It is still unclear whether colour encoding is as automatic as some researchers have suggested it is. Park and James (1983) and Park and Mason (1982) have suggested that colour is encoded intentionally in memory, while others argue that it is encoded incidentally (Backman, Nisson & Nouri, 1993; Hatwell, 1995; Ling & Blades, 1996). Patel, Blades and Andrade (1999) hold that if information is encoded without effort, then there should be no developmental effects on recall. However, they found that whilst children of four were as accurate in their colour judgements as adults, they were much better on recognition than recall tasks.

MEMORY AND AUTISM

Findings from research investigating memory functions in autism have produced mixed results. Recognition memory has been shown to be unimpaired in high functioning autism (Barth, Fein & Waterhouse, 1995; Benetto, Pennington, Rogers, 1996; Minshew, Goldstein, Muen & Payton, 1992; Minshew, Goldstein, Tayloret al., 1994; Renner, Grofer Klinger, Klinger, 2000), but some impairments have been found in those with severe cognitive impairment (Boucher & Warrington, 1976). However, immediate memory span for unrelated items (Hermelin & Connor, 1967; 1975; O'Connor & Hermelin, 1967) and cued recall (Boucher & Lewis, 1989; Boucher & Warrington, 1976; Tager-Flusberg, 1991) appears to be unimpaired, even in cognitively lower functioning individuals

The most consistently reported deficit is in free recall, especially when categorical relations among items can be used to aid recall. Such deficits have been reported even in these cognitively impaired children with autism (Boucher & Warrington, 1976;

Hermelin & O'Connor, 1967), as well as those from the higher-functioning end of the spectrum such as individuals with Asperger's syndrome (Bowler, Gardiner, Grice et al., 2000; Volkmar, Klin, Schultz et al., 1996).

Using various memory tasks, Bennetto et al. (1996) found that individuals with autism showed performance deficits in temporal order memory, source memory sentence and digit span, as well as on executive function tasks, such as the Wisconsin Card Sorting task and The Tower of Hanoi task. However, short and long term recognition and cued recall were unimpaired. Other researchers have found that individuals with autism only show poor performance on memory tasks requiring cognitive flexibility (Ozonoff & Strayer, 2001; Ozonoff & McEvoy, 1994). This lack of flexibility in children with autism manifests in a tendency to identify specific rules and apply them universally, whereas typically developing individuals change response strategies as the situation demands (Frith, 1970).

It is not clear whether children with autism are able to use semantic information to aid memory recall. For example, in one visual recognition memory task, Ameli, Courchesne, Lincoln et al., (1988) found that autistic subjects performed well with meaningful stimuli but poorly with meaningless stimuli, a pattern of performance consistent with semantic encoding seen in typical development. However, Tager-Flusberg (1991) found that children with autism were significantly poorer than matched controls at recalling lists of semantically related words in comparison to lists of semantically unrelated words. Frith (1970) observed deficits on studies using colour sequences, and suggested that difficulties in utilising semantic knowledge to aid memory in autism may not be limited to verbal material.

A more recent study of working memory in high functioning children with autism revealed impairments in using verbal encoding and rehearsal strategies (Joseph, Steele, Meyer & Tager-Flusberg, 2005). Working memory was assessed using verbal and non-verbal variants of a non-spatial, self ordered pointing test (Petrides & Milner, 1982). In the experiment children were required to point to a new stimulus in a set upon each presentation without repeating a previous choice. In a verbal condition, the stimuli were not easily named or verbally encoded. Participants were also administered a verbal span task to assess non-executive verbal rehearsal skills. The group with autism performed significantly less well in the verbal, but not the non-verbal self-ordered pointing test. However the autism and control group showed equivalent verbal rehearsal skills.

Koshino, Carpenter, Minshew et al., (2005) looked at whether individuals with autism might adopt a more visually orientated strategy in an n-back working memory task. In this experiment, individuals were shown sequences of twenty letters across three experimental conditions (0-back, 1-back, 2-back). In the 0-condition, participants were shown a target letter at the beginning of the sequence and told to respond when they saw the target letter. In the 1-back condition participants were told to respond when the same letter was presented twice in a row, and in the 2-back condition they were to respond when a letter matched the one previously presented in the sequence. Thus the working memory load was manipulated across conditions, but the visual information in the letter sequences remained constant. In line with the experimental hypothesis, imaging data showed less activation in the anterior regions and more activation in the posterior regions associated with visual processing in the autism group than in the control group. This finding is consistent with previous research showing reduced activation in the regions associated with higher level cognition in autism compared to controls (Just et al., 2004; Ring, Baron-Cohen, Wheelwright et al., 1999).

Such atypical information processing has also been highlighted in studies showing increased right hemisphere activation in response to speech stimuli in autism (Boddaert & Zilbovicius, 2002; Muller, Behen, Pierce et al., 1999). The processing of verbal information is typically seen to activate more regions in the left hemisphere in normal controls, whereas processing of nonverbal and spatial information is associated with right hemisphere processing (Owen, Stern, Look et al., 1998; Smith & Jonides, 1999, Smith, Jonides, Marshuertz et al., 1998). However, left hemisphere activation in response to nonverbal and spatial information may be seen in normal controls if they use phonological codes to encode stimulus. Increased right hemisphere activation in autism may occur because they code shapes without naming them (Boddaret & Zilbovicius, 2002; Muller et al., 1999). Koshino et al., (2005) propose that the neural architecture of the brain in autism differs to that of the typically developing brain, and that weaker anterior memory activation in autism could reflect a greater reliance on visual features. Koshino et al., 2005 also found less synchronisation among brain areas in autism compared to control groups, therefore providing further support for the previously mentioned underconnectivity theory proposed by Just et al., 2004.

The three experiments to be presented in this chapter investigated memory for colours or colour labels. The rationale for the studies is that individuals with autism are proposed to rely on visual coding strategies to a greater extent and verbal coding strategies to a lesser extent than those with typical development (Koshino et al., 2005).

A paired-learning paradigm, in which children were exposed to a picture of an animal paired with either a colour or a colour name in familiarisation phases, was used in all three studies. In the test phases, children were shown the pre-exposed animals together with the original pre-exposed colour and three distractor colours (experiments nine and ten), or with the pre-exposed colour word and three distractor colours words (experiment eleven). Children were required to point to the target they had previously seen paired with the animal currently on view. In experiments nine and eleven, a verbal or perceptual encoding strategy could facilitate task success. However, for experiment ten, a verbal encoding strategy would be unsuccessful as distractor colours were different exemplars drawn from the same colour categories.

EXPERIMENT NINE - COLOUR MEMORY AND LABELS (1)

Procedure & Participant Sample

The participant sample was the same for all of the three experiments reported in the chapter. Thirteen children with HFA aged between 7 years 11 months to 15 years 0 months (mean 10. 9) with non-verbal IQ ranging between 78-109 (mean 91.17), and thirteen children with LFA aged between 7 years and 2 months to 15 years and 8 months (mean 11.4) with non-verbal IQ ranges ranging between 55-69 (mean 62.15) were matched with children with TD and MLD respectively, for age, gender and non-verbal IQ scores using Ravens Matrices (Raven, Court, Raven 1988). The children's psychometric data are shown in table 5.1.

Table 5.1: Psychometric data for the participants

Group	Age		Ravens		BPVS		Verbal Mental Age	
	Mean	sd	Mean	sd	Mean	sd	Mean	sd
Autism=26	**11.2**	**2.52**	**76.31**	**16.87**	**56.12**	**12.23**	**6.30**	**1.56**
HFA=13	10.9	2.69	91.17	10.75	64.42	9.75	7.2	1.59
LFA=13	11.4	2.46	62.15	6.82	47.69	8.41	5.4	0.91
Controls=26	**11.21**	**2.24**	**76.38**	**16.77**	**77.00**	**21.63**	**8.47**	**2.68**
TD=13	10.8	2.45	89.07	13.33	89.00	21.58	9.9	3.12
MLD=13	11.5	2.07	65.54	7.73	62.23	10.31	7.1	0.97

Apparatus

The colours used in the experiment were generated the same way as in experiment six (colour discrimination task) reported in chapter four. The experiment was written in e-prime and presented on a computer. Animal pictures were taken from the Snodgrass and Vanderwart (1980) Picture Norms set. Colours remained on screen until the children responded

Stimuli

Four Focal colours red, blue, green, yellow all of 5 hue and were 100*100 pixels in size. All colours were kept brightness (level 6) and saturation (level 6). Animals were bmp images of a dog, cat, rabbit and pig and were 200*200 pixels in size.

Familiarisation Trials: The children were told that they were to see each of the animals again and had to point to which was the animal's favourite colour. Children saw an individual animal with its colour four times each (16 times in total). They saw a pig with green (5G 6/6) a dog with a red (5R 6/6) a cat with a blue (5B 6/6) a rabbit with a yellow (5Y 6/6). The animal was shown directly above the colour patch with 2cm in between (example of stimuli is shown in appendix).

Experimental Trials: This experiment adopted a paradigm used previously for determining pitch memory in autism (Heaton et al., 1998; Heaton, 2003). The children were told that they were to see each of the animals again and had to point to which was the animal's favourite colour. This time the children saw each animal individually appear on the screen with all four colour patches underneath. The children were asked to point to which of the colours was that particular animal's favourite colour. The stimuli remained on screen until the children gave a response by pointing to the one of the colours. Responses were made by the experimenter via the computer which recorded the individual responses. The children had four attempts at each animal (16 trials). Animals were shown in a random order.

Results

Table 5.2: Means and standard deviation for all participants on experiment nine

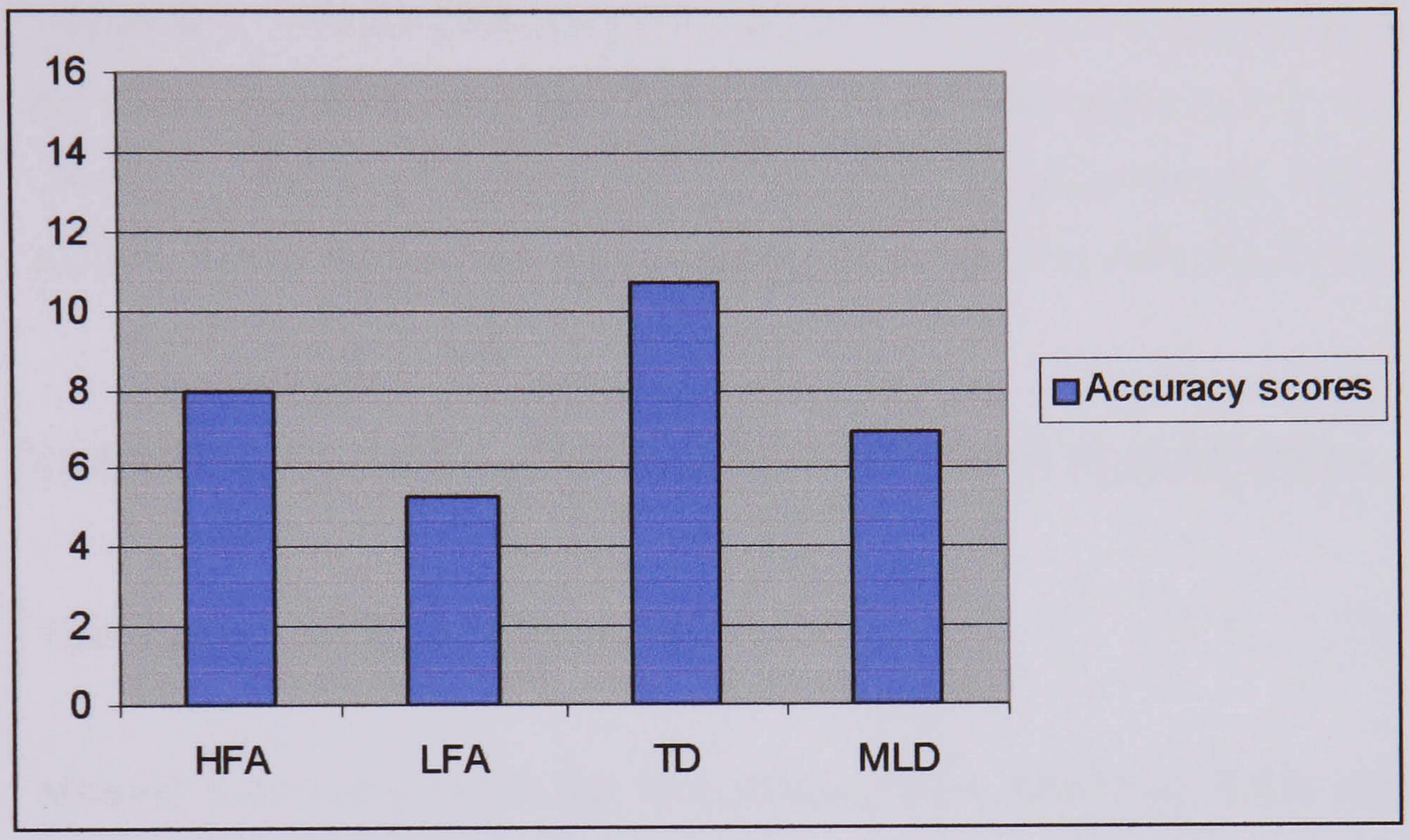
Group	Mean	Standard deviation
Autism=26	**6.65**	**4.09**
HFA=13	8.00	4.59
LFA =13	5.31	3.17
Controls=26	**8.81**	**5.19**
TD=13	10.69	5.22
MLD=13	6.92	4.59

*Optimal score =16

** scores below 6 equal chance (Binomial test)

An initial Analysis of Variance revealed no significant differences between the children with autism and controls ($F(1,51)=2.76$, n.s.). However, as cognitive impairment had been shown to have significant effects in the experiments reported in chapter four, a second analysis with four groups (HFA, LFA, TD, MLD) as the between-group factor was carried out. This analysis revealed a significant main effect of group, (F(3,51)=0.356, p<.05) which is shown in Figure 5.1 below

Figure 5.1: Significant main effect of group on experiment nine.



Independent t-tests with Bonferroni adjustments were carried out on the main effect. These showed no significant difference between groups with HFA and LFA, (t(24)=1.74,n.s.), between groups with HFA and TD (t(24)=-1.39, n.s.), between groups with HFA and MLD (t(24)=.59, n.s.), between groups with TD and MLD (t(24)=1.96, n.s.) and between groups with LFA and MLD (t(24)=-1.044, n.s.). The only comparison that reaches statistical significance was the TD and LFA comparison (t(24)=3.18, p<.05).

Correlations carried out on the complete data set showed that test scores did not correlate with age (r = 1.77, n s.) or non-verbal IQ (Ravens Matrices) (r = .19, n.s.). However, there was a significant correlation between verbal IQ (BPVS) and test scores (r=.39, p<.01). This pattern of correlations was seen again when the data from the two groups without autism (TD & MLD) was pooled. Correlations between test scores and age (r = .18, n.s.) and test scores and non-verbal IQ verbal IQ (r = .16, n.s.) were not significant, but the correlation between test scores and verbal IQ reached significance (r = .39, p<.05). For the pooled autism data (HFA & LFA), test scores did not correlate with any of the matching variables (age, r = 1.8, n.s.; non-verbal IQ, r = .24; verbal IQ, r = .20, n.s.). These correlations showed that whilst the most verbally able children without autism showed the best test performance, this pattern was not seen in the autism group.

EXPERIMENT TEN - COLOUR MEMORY AND PERCEPTION

Apparatus same as experiment nine

Stimuli: Four focal colours red, blue, green, yellow all of 1hue, 5 hue and 9 hue and were 100*100 in size. All colours were kept at brightness level six and saturation level six. Animals were the same as experiment nine.

Procedure

The familiarisation trials were exactly the same as for Experiment Nine. However, this time the children were asked to look very carefully at the animals' favourite colours and to try to remember the exact colour. In the experimental trials the children were shown the same animals again, but this time underneath the animal were three colour patches of the same colour (1hue, 5hue, 9 hue of either blue, green, yellow, red) with 5 hue of each colour being the original paired with animals. The results from experiment six (chapter four) had provided information about colour discrimination levels in participants of this age and the hues were 1, 5 and 9. The position of the colours was randomised as was the order of presentation of the stimuli. Again, the children responded by pointing to the correct colour patch on the computer and the experimenter entering the response on to the computer. The stimuli remained on screen until the children gave a response by pointing to the one of the colours. Example of the stimuli is shown in the appendi

Table 5.3 shows the means and standard deviations for the correct number of identifications in experiment in experiment ten.

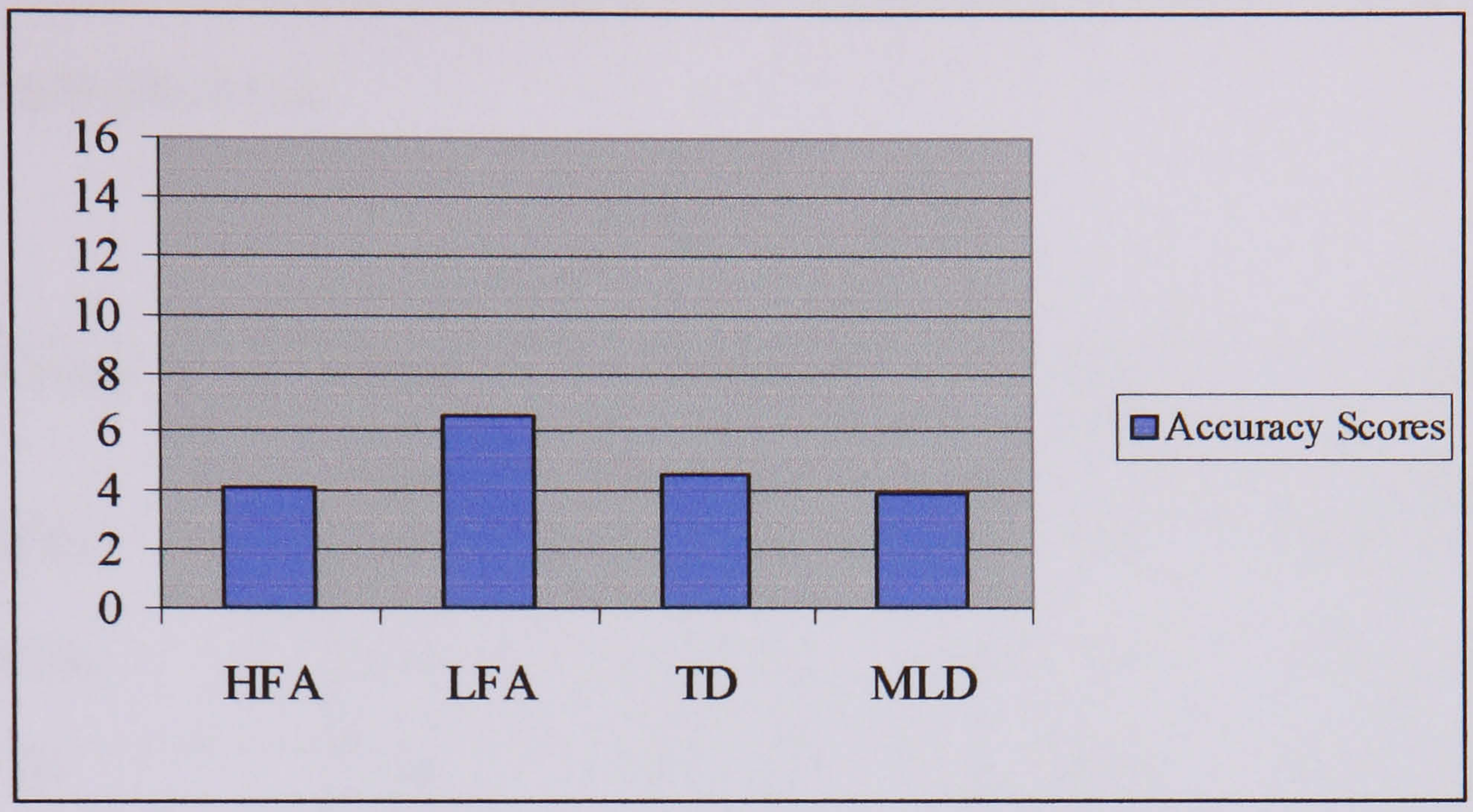
Table 5.3: Means and standard deviations for participants' correct scores in experiment ten.

Group	Mean	Std.dev.
Autism=26	**5.38**	**2.65**
HFA=13	4.15	2.82
LFA=13	6.62	1.85
Controls=26	**4.23**	**1.95**
TD=13	4.54	2.82
MLD=13	3.92	1.44

*Optimal score =16

An initial Analysis of Variance revealed no significant differences between the children with autism and their controls on experiment nine ($F(1,51)=3.196$, n.s.). Again a second analysis in which they are subdivided in four groups (HFA, LFA, TD, MLD) was carried out. This analysis revealed a significant main effect of group which is shown in Figure 5.2 overleaf

Figure 5.2: Main effect of group in experiment ten



Independent t-tests with Bonferroni adjustments were carried out on this data. These showed no significant difference between groups with HFA and LFA (t(24)=-2.62, n.s.), HFA and TD (t(24)=-3.76, n.s.), HFA and MLD (t(24)=.26, n.s.), TD and MLD (t(24)=.801, n.s.) and TD and LFA (t(24)=-2.49, n.s). Only the LFA and MLD comparison reached statistical significance (t(24)=4.14,p<.001).

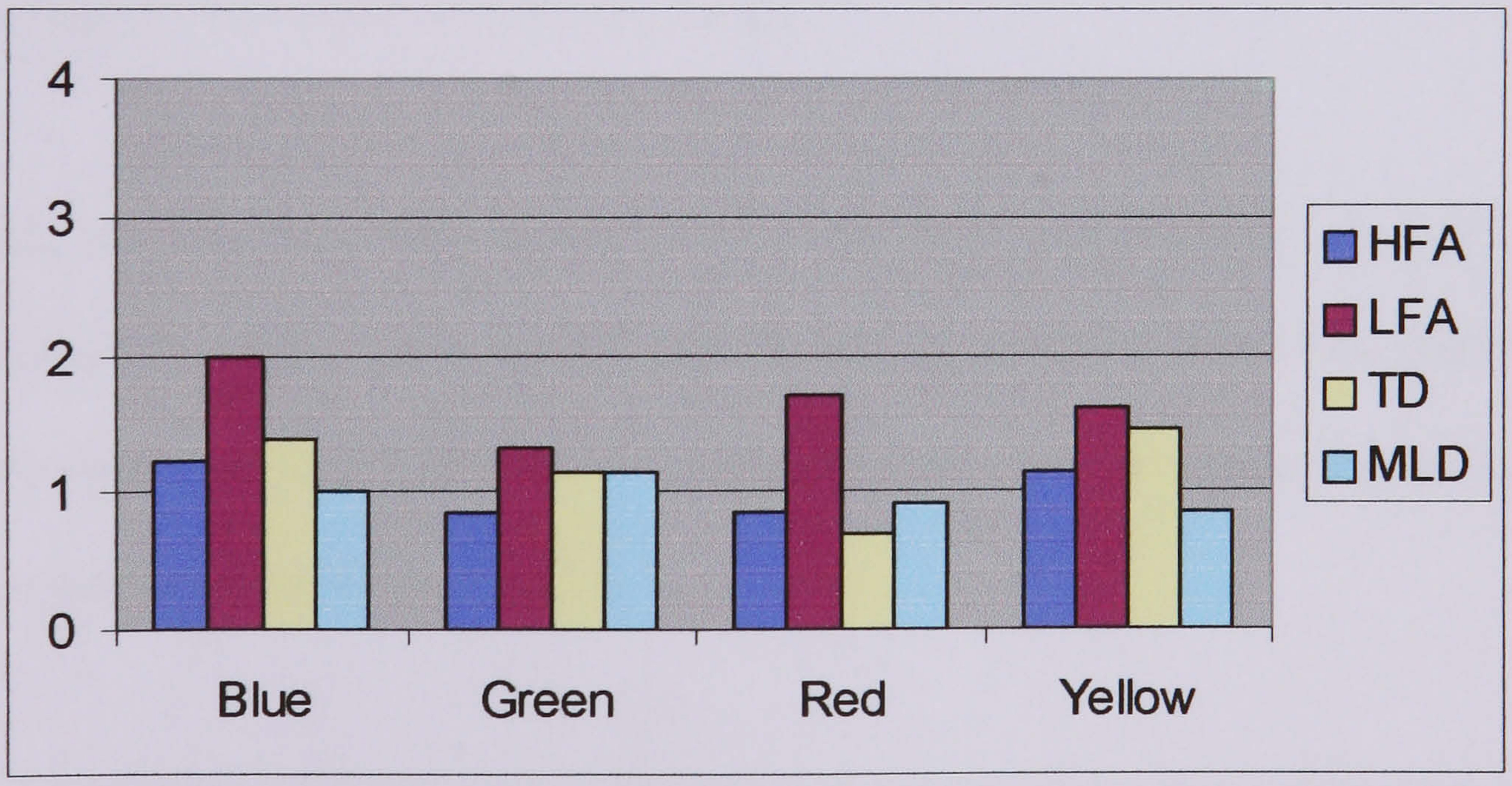
The target stimuli (5hue) and the different distractor patches (1hue and 9hue) fell within category for the blue and green categories. However, some distractor patches fell outside of the target category for the red and yellow, and these were analysed separately. Table 5.4 shows the means and standard deviations across colour categories for experiment ten and the pattern of results is illustrated in figure 5.3.

Table 5.4: Means and standard deviations for the different colour categories on experiment ten.

Group	Blue Mean	Blue sd	Green Mean	Green sd	Red Mean	Red sd	Yellow Mean	Yellow sd
HFA	1.23	1.01	0.85	1.14	0.85	0.80	1.13	1.16
LFA	2.00	1.00	1.31	0.86	1.69	0.95	1.62	1.04
TD	1.38	1.19	1.15	1.41	0.69	0.75	1.46	1.19
MLD	1.00	1.00	1.15	0.80	0.92	0.86	0.85	0.80

*Optimal Score=6 for each colour.

Figure 5.3: Mean number correct across colour categories on experiment ten.



An initial analysis of variance was carried out on the total number correct on experiment ten on the blue and green categories for the main two groups. Groups (autism/controls) was the between factor and condition (number correct on blue and green) as the within group factor. The analysis showed no significant main effect of group, $F(1,50)=.62$, n.s.), no significant main effect of condition, $F(1,50)=2.05$, n.s.) and no significant group by condition interaction, $F(1,50)=1.54$, n.s.).

An analysis of variance was then carried out on the total correct for blue/green range on the four subgroups. This showed no significant main effect of group ($F(3,48)=1.73$, n.s.) and no significant main effect of condition ($F(1, 48)=2.00$, n.s.). There was also no significant group by condition interaction ($F(3,48)=0.74$, n.s.).

A second analysis was carried out on the total number correct on experiment ten on the red and yellow categories for the main two groups. Group (autism/controls) was the between factor and condition (number correct on red and yellow) as the within group factor. The analysis showed no significant main effect of group, $F(1,50)=2.83$,n.s.), no significant main effect of condition, $F(1,50)=2.28$,n.s.) and no significant group by condition interaction, $F(1,50)=3.37$,n.s.).

An analysis was then carried out on the four subgroups for the red and yellow categories. Again there was no significant main effect of group ($F(3,48)=2.54$, n.s.) or condition ($F(1,48)=2.39$, n.s.). There was also no significant group by condition interaction ($F(3,48)=1.59$, n.s.).

Correlations were carried out and showed that for the autism group memory recall of green and blue did not correlate with performance on the BPVS ($r=-.38$, n.s.), Ravens Matrices ($r=-.13$, n.s.) or age ($r=-.032$, n.s.). Similarly, memory recall for the red and yellow stimuli showed no correlation with BPVS ($r=-.28$, n.s.), Ravens Matrices ($r=.17$, n.s.) or age (r=-.14, n.s.). The same pattern emerged for the control groups. Again memory recall of green and blue did not correlate with performance on the BPVS (r=.21, n.s.), Ravens Matrices (r=.21, n.s.) or age (r=-.104, n.s.). Memory recall for the red and yellow stimuli also showed no correlation with BPVS (r=.032, n.s.), Ravens Matrices (r=.22, n.s.) or age (r=-.089, n.s.).

Correlations were then carried out on the complete data set (all colours and all groups). These showed no significant effects of age (r = -.05, n.s.) or non-verbal IQ (Ravens Matrices) (r = -.21) and test scores. However there was a significant negative correlation between verbal IQ (BPVS) and test scores (r=-.30, p<.05). When the data from the two groups without autism (TD & MLD) was pooled, no correlations reached significance (age and test scores, r = -.11, n.s.; non-verbal IQ and test scores, r = .10, n.s; verbal IQ and test scores, r = .04, n.s.). For the pooled autism data (HFA & LFA) test scores did not correlate with age (r = -.21, n.s.). However, there were significant negative correlations between test scores and non-verbal IQ (r = -.59, p<.01) and test scores and verbal IQ (r = -.47, p<.04). The finding that the least able children performed at the highest levels on this task will be further investigated.

EXPERIMENT ELEVEN - COLOUR MEMORY AND LABELS (2)

Procedure

Stimuli

Four bmp images of animals (chicken, swan, duck, cow) and four colour words (RED, YELLOW, GREEN, BLUE) typed in Times Roman Font Size 16.

Procedure

The procedure was the same as for Experiment Nine, but this time the children saw animals with colour names. A different set of animals was used. Children were told that they would see an animal with a colour name and that they had to try and remember which colour name they saw with which animal. As with the previous experiments, they saw an animal with a colour word 2 cm underneath (Swan with RED, Cow with BLUE, Chicken with GREEN and a Duck with YELLOW. They saw each animal and its colour word four times each in a random order (16 trials). Before the testing trials began, the children were told they would see each animal again with a choice of four colours. They were told to point to the colour they had seen previously with the animal. In order to have a suitably large print the colours were presented down the right hand side of the screen rather than below. Children responded by pointing to one of the colours. Responses were recorded by the experimenter pressing a key that registered the response that the child made. The stimuli remained on screen until the children gave a response by pointing to the one of the colours. Examples of the stimuli is shown in the appendix.

The means and standard deviations for accurate identification of colour words are shown in table 5.5 below.

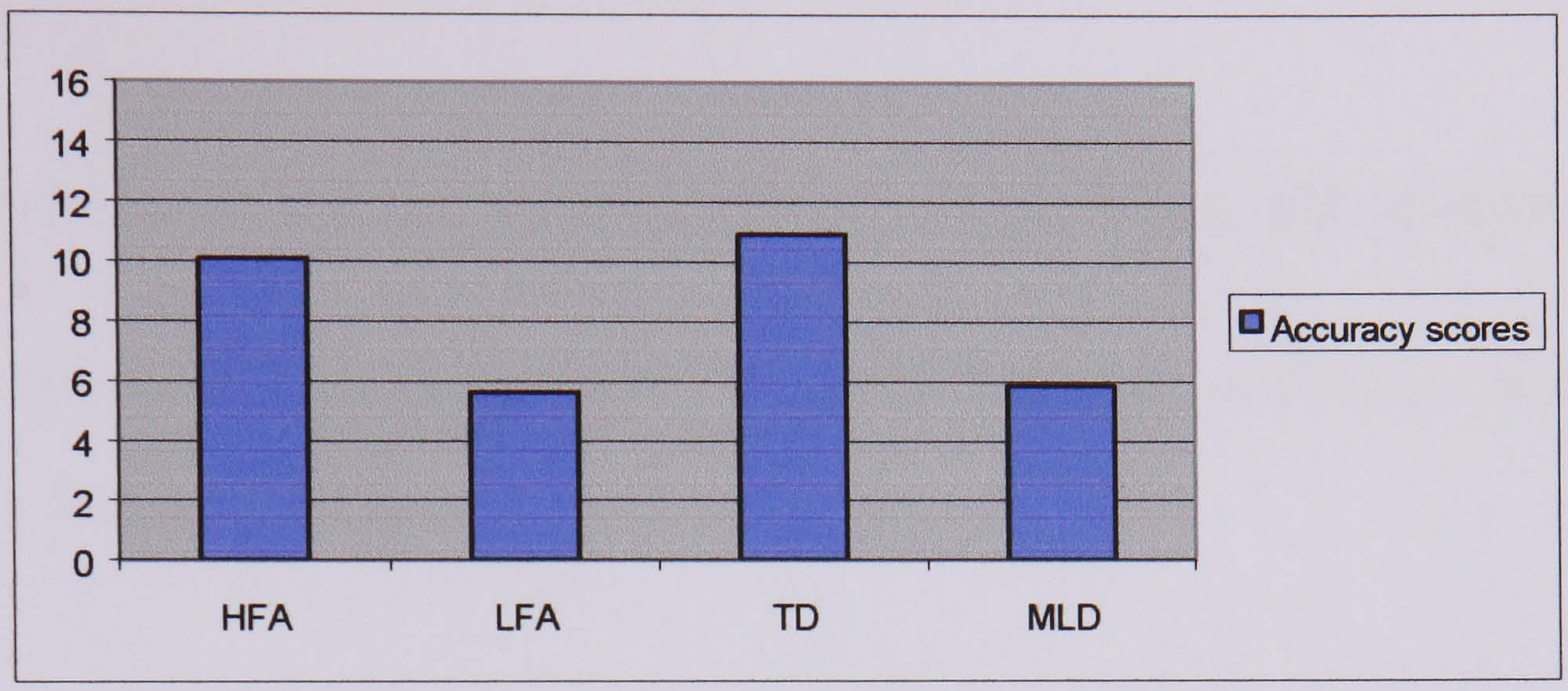
Table 5.5: Means and standard deviations for correct identification of colour words in experiment eleven

Group	Mean	Sd
Autism=26	**7.85**	**4.91**
HFA=13	10.08	5.14
LFA=13	5.62	3.59
Controls=26	**8.38**	**5.32**
TD=13	10.92	4.94
MLD=13	5.85	4.54

*Optimal score=16

Again, an initial Analysis of Variance revealed that there were no significant differences between the children with autism and the controls on experiment eleven ($F(1,51)=0.144$, n.s.). However, the sub-group analysis did reveal a significant effect of group ($F(3,51)=4.75$, $p<0.05$) which is shown in figure 5.4.

Figure 5.4: Main effect of group on experiment eleven.



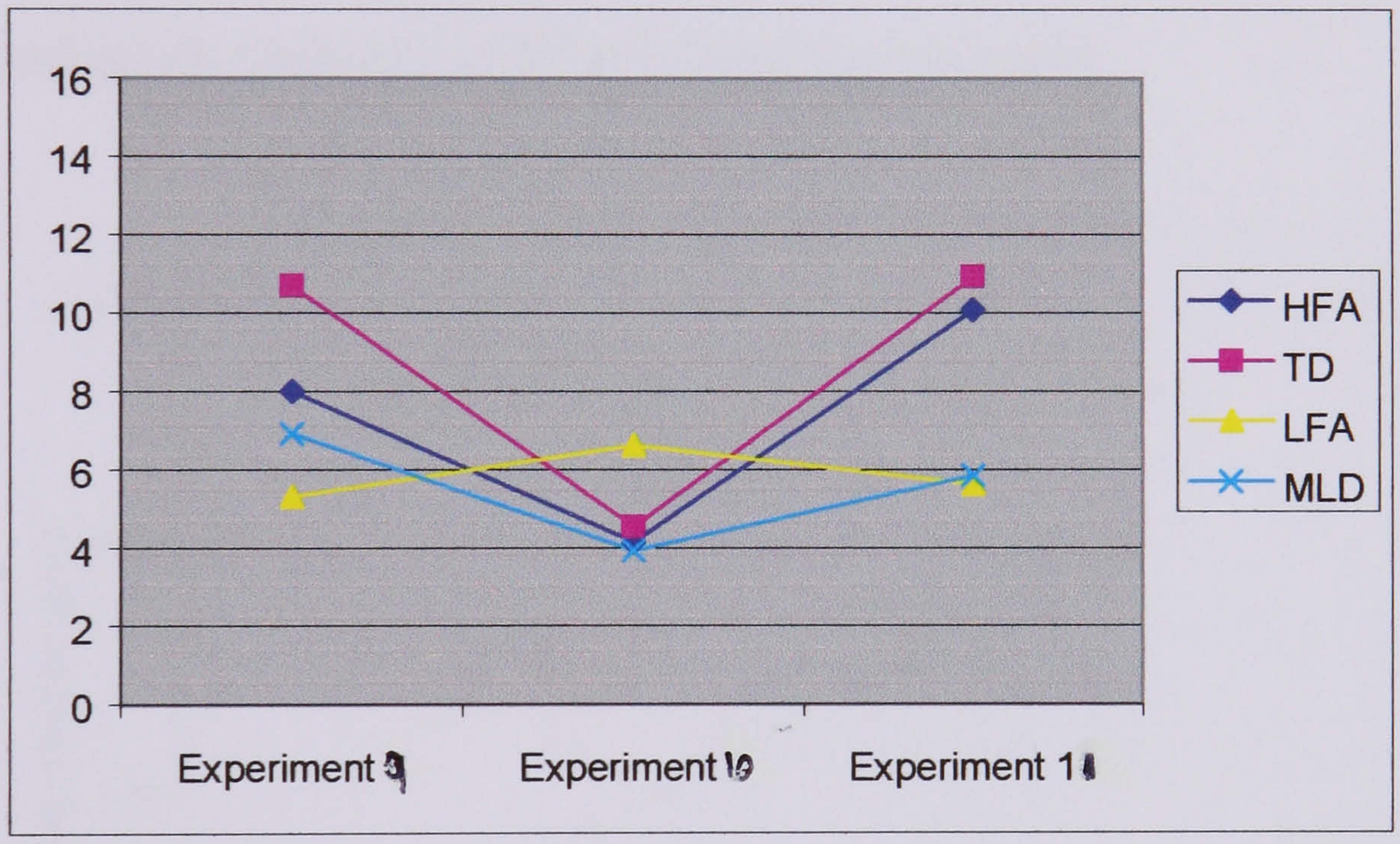
Independent t-tests with Bonferroni adjustments were carried out on this data. These showed no significant differences between the groups with HFA and LFA (t (24)=2.56, n.s.), HFA and TD (t (24)=-.43, n.s.), HFA and MLD (t (24)=2.22, n.s.), TD and MLD (t (24)=2.73, n.s.) or LFA and MLD (t (24)=-.14, n.s.). Only the comparison between groups with TD and LFA reached statistical significance (t (24)=3.13, p<.05).

Correlations carried out on the complete data set showed no significant effects of age (r = .00, n.s.). However, the non-verbal IQ and test score correlation was significant (r= .46, p<.01) as was the verbal IQ and test scores correlation (r=.44, p<.01). This pattern of correlations was seen again when the data from the two groups with autism (HFA & LFA) was pooled: correlations between age and test scores were not significant (r = -.00, n.s.) but correlations between test scores and non-verbal IQ (r = .54, p<.01) and test scores and verbal IQ (r = .50, p<.01) were significant. For the pooled control participants data (TD & MLD) test scores did not correlate with age (r =.00, n.s.). The correlation between tests scores and non-verbal IQ approached statistical significance (r = .38, p<.054) and the correlation between verbal IQ and test scores was significant (r = .50, p<.01).

ANALYSIS OF DATA FROM EXPERIMENTS NINE, TEN AND ELEVEN.

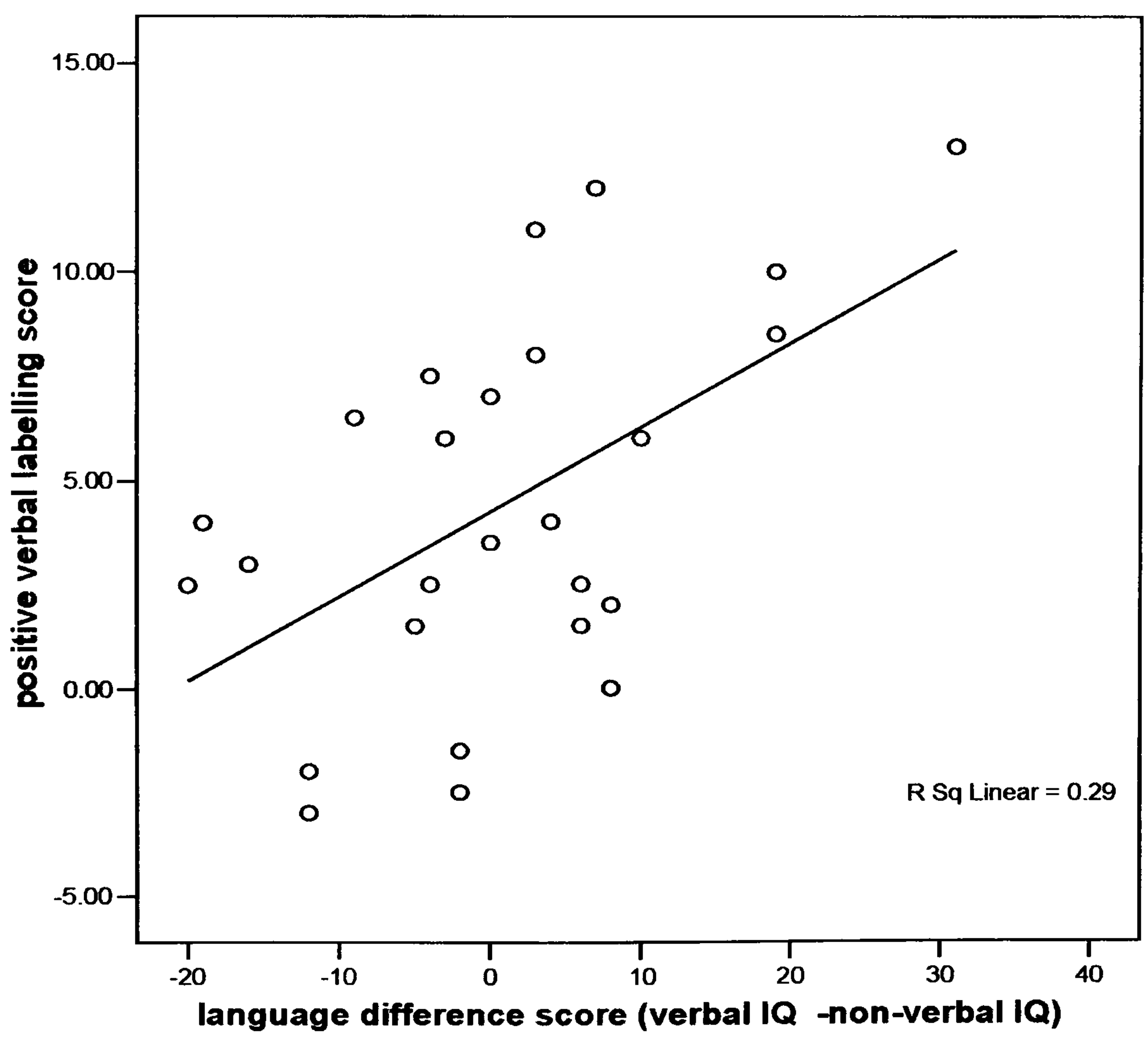
Levels of performance across the three experiments presented in this chapter are shown in figure 5.5 below.

Figure 5.5: Performance across experiments nine, ten and eleven.



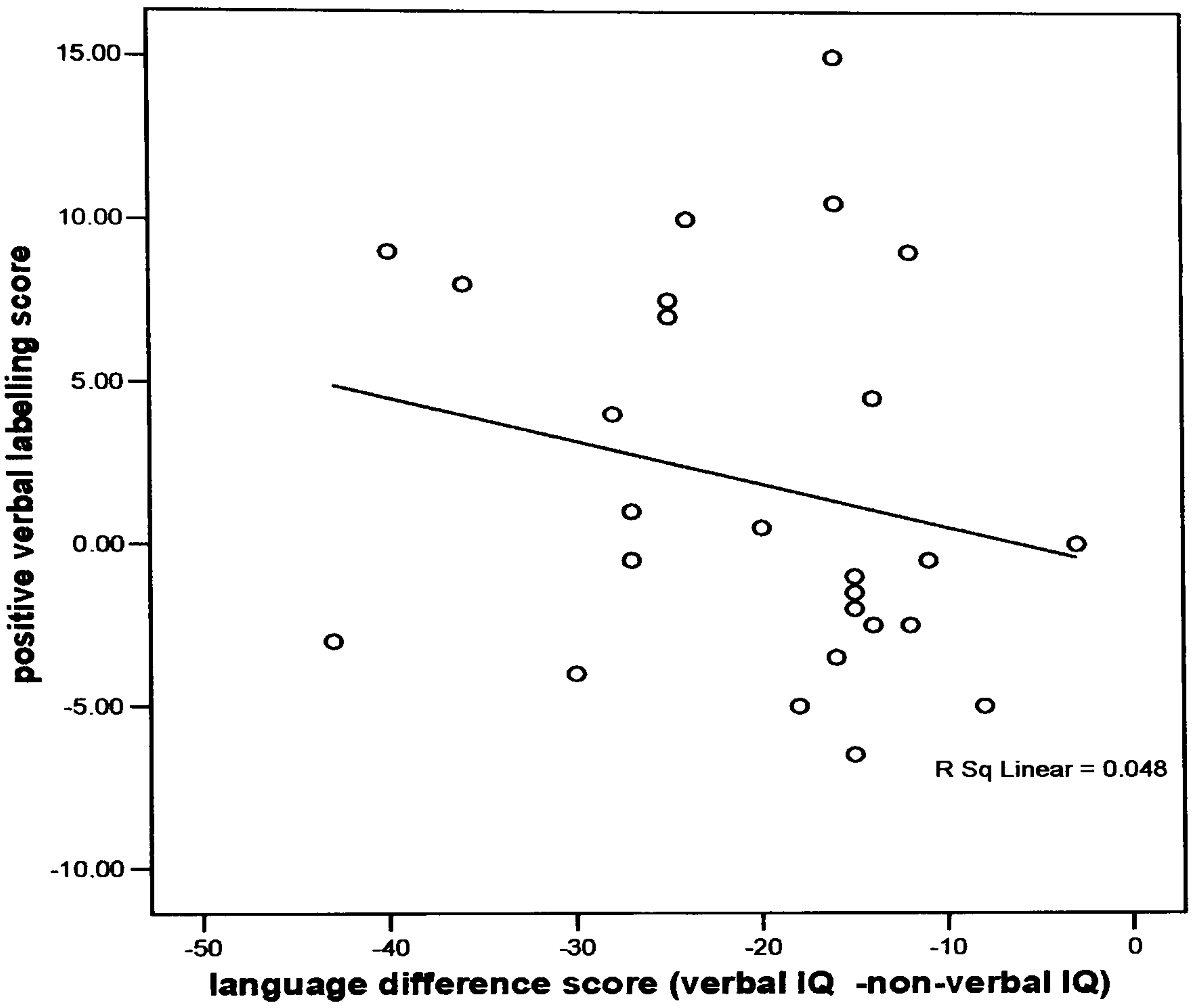
In order to further explore group performance across the three experiments, transformations were carried out on the data. Although the two intelligence measures used in the studies (Ravens matrices and BPVS) were highly correlated within groups (Autism, r = .82, p<.01; Controls, r = .84, p<.01), it was interesting to see whether participants within the autism group with a significantly lower verbal than non-verbal IQ would rely on verbal labelling to a lesser extent than those without such a discrepancy. Therefore a measure of relative language ability was generated by the subtraction of non-verbal IQ scores (Ravens matrices) from verbal IQ scores (BPVS). The second new measure was a positive score for verbal labelling. This was computed by subtracting the scores from experiment ten (that did not rely on verbal labelling), from the averaged scores for experiments nine and eleven (that did rely on verbal labelling). Correlations carried out on these two variables were positive and significant for the pooled control data (TD and MLD) ($r= .54$, $p<.01$) showing that the presence of relative language ability co-occurs alongside positive verbal labelling ability. This is illustrated in figure 5.6.

Figure 5.6 Scatterplot for positive correlation between positive verbal labelling and relative language ability in control participants.



The correlation between the language difference score and the positive verbal labelling score for the autism group was negative but not significant ($r = -.22$, n.s.). This is shown in figure 5.7

Figure 5.7 Scatterplot showing non-significant correlation between positive verbal labelling and relative language ability in participants with autism



This finding suggests that the participants with autism for whom verbal IQ is relatively unimpaired in relation to non-verbal IQ (verbal IQ – non-verbal IQ difference score) do not appear to do better on positive verbal labelling than those with greater relative language impairment. This was further investigated. Correlations between pooled, averaged scores for experiments nine and eleven (verbal labelling experiments) and verbal IQ were significant for both the autism group ($r = .5$, $p<.01$) and controls groups ($r = .43$, $p<.01$). However, whilst there was a significant positive correlation between these pooled averaged scores and non-verbal IQ in the autism group ($r = .48$, $p<.05$), this was not significant for controls ($r = .3$, n.s.).

Correlations carried out on data from experiment ten (perceptual memory) were significant and negative for both non-verbal IQ ($r = -.47$, $p<.05$) and verbal IQ ($r = -.59$) for the autism group. Neither correlations (non-verbal IQ and experiment ten, $r = .1$, n.s.; verbal IQ and experiment ten, $r = .04$, n.s.) were significant for controls. These correlations confirm that within the autism group, low IQ, both verbal and non-verbal are associated with good perceptually based memory performance.

DISCUSSION

The experiments in this chapter tested the hypothesis that participants with autism would rely on visual coding strategies to a greater extent and verbal coding strategies to a lesser extent than age and intelligence matched controls. The findings from the studies provided limited support for the hypothesis in that this appeared to be the case for participants with autism who possessed additional non-verbal and verbal impairments only.

In experiment nine, where verbal labelling would seem likely to result in optimal performance, typically developing children achieved the highest test scores, and four of the thirteen TD participants achieved a ceiling score of sixteen. Two of the participants with HF with autism and two with MLD also performed at ceiling on the task, and performance for neither of these groups was significantly poorer than that of the children with typical development. The LFA group mean was significantly poorer than that of the TD group and many participants performed at chance levels.

The findings from experiment ten showed a reversal in the pattern of performance across participant groups. Although experiment ten was very similar to experiment nine in requiring participants to encode a colour and an animal in memory, the response options in the test phase all had the same colour label, and successful retrieval depended on perceptual memory. The results from the experiment showed that participants with LFA performed at significantly higher levels than those with typical development. Performance across the three groups without LFA did not show significant differences. There was also no significant difference across colours. For the red and yellow stimuli, it could have been predicted that memory recall may have been easier than for blue and green, as distractors fell across category to the target colour. However the children from all groups showed a similar level of performance across colours.

Experiment eleven also required paired learning, but here verbal labels were made explicit and there was no exposure to colours in the familiarisation trials. In this experiment, the HFA and TD groups performed at similar levels, and whilst the performance of the participants with MLD was lower than that of the two cognitively impaired groups this did not reach statistical significance. The lowest levels of performance were seen in the LFA group and the difference between their scores and those of the TD children was statistically significant.

An analysis of the data from the three experiments was carried out. An important aspect of this was to investigate IQ and task performance correlates. Although control participants were closely matched for chronological age and scores on Raven's matrices, autism is characterised by an uneven profile of cognitive abilities, and language abilities are sometimes lower than would be predicted on the basis of non-verbal intelligence. It was interesting that whilst the participants with MLD achieved lower overall performance than the other group without autism (TD), their pattern of performance was also similar, especially on experiments nine and ten that did not require reading ability. It is therefore clear that low IQ does not result in compromised verbal memory strategies and reliance on perceptual memory. It was also interesting that the participants with HFA, whose verbal IQ scores were very similar to those of the MLD participants, showed a level and pattern of performance that was much more like that of the cognitively unimpaired TD controls.

When a difference score, that took into account any potential discrepancies between verbal and non-verbal IQ, was correlated with a positive labelling score that was derived from the scores for the three experiments, the data for the participants without autism was significant and positive. This showed that participants without a large discrepancy between non-verbal and verbal IQ scores performed well in experiments where verbal labelling would be expected to convey an advantage. When this was directly investigated in correlations between verbal IQ scores and pooled averaged scores from experiments nine and eleven, these were also found to be positive and significant. Correlations carried out on these scores and non-verbal IQ data were not significant. Neither verbal nor non-verbal IQ data correlated with performance on experiment ten that tested perceptual memory. Taken together, the data from the participants without autism showed that performance levels were highest in experiments where memory could be facilitated by verbal labelling. The extent to which this facilitation occurred was largely determined by the individual participant's verbal intelligence.

The results of the analysis of the data from the groups with autism revealed a very different pattern to that of the controls. When correlations between the language difference scores and the positive labelling scores were carried out, this was non-significant and negative. This meant that individuals who did not have a much lower verbal than non-verbal IQ did not appear to show increased verbal labelling. Analysis of the pooled averaged data for experiments nine and eleven, like the control group data, correlated positively with verbal IQ. However, unlike the control data, these scores also correlated with non-verbal IQ. The analyses of the individual studies had shown that the performance of the HFA group was frequently very similar to that of the TD controls with whom they were matched on non-verbal IQ. Furthermore, non-verbal and verbal IQ correlated in the autism group, and HFA participants also possessed higher verbal IQ than the low functioning group. Most striking of all was the finding that scores for experiment ten, that tested perceptual memory, correlated negatively and significantly with both verbal and non-verbal IQ. This clearly showed that the LFA participants, but not HFA participants, were advantaged on a task that relied on perceptual memory. This finding will be discussed with reference to the findings from the studies reported in chapter four and current theories of autism and colour processing.

In experiment five, reported in chapter four, comprehension of colour names was found to be unimpaired in autism. With the exception of a small group of children who may have had generally poor productive language, colour naming was also good. Even the children who had difficulty in naming colours knew which colour names matched the presented colour chips. When considered in the light of the findings from the current chapter, it appears that whilst children with low functioning autism readily acquire colour terms, these tend to influence their processing of colour stimuli to a smaller extent than is usual. It was also interesting that these children appeared to rely more heavily on perceptual information in memory than cognitively impaired children without autism.

In experiment six, reported in chapter four, neither high nor low functioning children with autism performed better than controls without autism on the perceptual discrimination task. Indeed the LFA group showed the lowest levels of performance overall. It therefore does not appear that qualitatively different performance seen in the LFA group in experiment ten can be a result of enhanced perceptual processing in autism. Furthermore, the participants with TD, HFA and MLD who had also participated in experiment six were easily able to discriminate colours at perceptual distances similar to those used as distractors in experiment ten. It may then be the case that their performance was poor because the memory representations laid down in the training trials were primarily linguistic, and the level of perceptual detail encoded was not sufficient to meet task demands in experiment ten. Verbal IQ correlated positively with performance on the two experiments (nine and eleven) where verbal encoding would lead to good performance in the participants without autism, and there was no correlation between task performance and non-verbal IQ, a result that reflected the good performance of some MLD participants. It was particularly interesting, given that enhanced perceptual processing has been proposed to characterise autism regardless of intellectual level and that language is an area of difficulty in autism, that the group with HFA also performed better on the experiments where verbal encoding facilitated good task performance.

In the discussion of chapter four, atypical perceptual categorisation was attributed to atypical language in HFA. Specifically, it was suggested that a tendency towards concrete and literal language would result in narrow category boundaries. However, such effects are likely to be subtle, primarily influencing stimuli that possess a degree of ambiguity (e.g. category boundary colours). In experiment five (chapter four), the HFA participants had achieved ceiling performance on the colour word comprehension and production task, and the colours presented with the animals in the training trials in experiment ten were typical exemplars of their colour categories. These factors might well contribute to the adoption of a verbal memory strategy. Also relevant is the fact that participants completed experiment ten after they had completed experiment nine, and there was no indication in the training trials for experiment ten that distractor colours in the test trials would be drawn from the same colour categories and a verbal coding strategy would be ineffective.

The findings from the LFA group were striking in that exceptional performance on experimental tasks is rarely seen in the least intellectually able participants. Whilst these individuals did not show enhanced perceptual processing of colours, they appeared to have encoded more of this type of information during the familiarisation trials. Whilst it is clearly the case that this should have resulted in good performance on both experiments nine and ten, their levels of performance across the two experiments did not show large changes, and the small increase in test scores on experiment ten may reflect increasing familiarity with the experimental paradigm. It could also be argued that the perceptual features of the written colour words would have increased saliency for the LFA participants, thereby enabling them to perform as well on this condition as the MLD controls, who were clearly unable to adopt a perceptual encoding strategy (experiment ten). It thus appears that cognitively impaired individuals with autism differ from individuals in whom these disabilities do not co-occur in encoding more perceptual than verbal information. This will be further discussed in the final chapter.

In the following chapter a case study of an able boy with Asperger syndrome (J.G.) and an obsession with the colour blue will be presented. J.G. completed the experimental tasks presented in chapters four and five, and for comparison purposes his data will be compared to that of the participants with HFA and TD who participated in these earlier studies.

CHAPTER SIX

INVESTIGATING THE IMPLICATIONS OF COLOUR OBSESSIONS IN AN ABLE BOY WITH ASPERGER SYNDROME

Summary: In this chapter the case of J.G., an eleven year old boy with Asperger syndrome and an obsession with the colour blue, is reported. Background information on J.G. was derived from interviews with J.G. and his mother, as well as from school reports. Assessment using the Sensory Profile test (Dunn, 1999) revealed significant difficulties across all sensory modalities, in relation to norms derived from both typical and developmentally atypical populations. The findings from experimental studies showed that J.G. improved reading performance with a self-selected overlay that corresponded to his colour obsession. However, he showed no colour vision abnormalities as measured by the City University Colour Test (3rd edition; Fletcher, 1998) or the Ishihara Colour vision test (Ishihara, 1970), and performed at ceiling on tests of colour word production and comprehension. Further results revealed exceptional perceptual discrimination of avoided colours and poor perceptual discrimination of blue. J.G. showed a similar pattern of performance to other HFA participants on a task assessing category boundaries across the blue/purple range, although further analysis showed that his blue category was narrower and his green category was broader than theirs. His cross-category discrimination scores were consistently at ceiling. On three experiments assessing memory, J.G.'s performance was consistent with a verbal colour memory strategy. The results from J.G.'s tests were interpreted within the context of the findings from group studies described in the earlier chapters and current theories of autism and colour processing.

BACKGROUND

The subject of this chapter, J.G., first underwent formal diagnostic testing between the ages of three and a half to four years old. During this time he was formally diagnosed with an autism spectrum disorder (Asperger Syndrome), and was also found to be suffering from Attention Deficit Hyperactivity Disorder and Verbal/Spatial dyspraxia. Data from the Children's Communicative Checklist (Bishop, 1998) were collected during this time, and confirmed that his profile of communicative strengths and weaknesses was consistent with that characteristic of Autism Spectrum Disorders.

J.G. has an older brother with dyslexia and many autism spectrum characteristics, and his parents noted unusual behaviours in J.G. from birth. For example, he responded very negatively to physical contact and seemed most as ease when left on his own. His development was extremely uneven with normal or good development in walking and potty-training and poor development of language. Some savant abilities were in evidence early on, and he is reported to have been able to dismantle complicated electrical equipment and clocks by the age of two years. Consequently J.G.'s parents ensured that the house was rewired so that electrical equipment could be overridden using one switch.

J.G.'s language onset was significantly delayed, and he did not attempt to speak until around the age of four. Currently, J.G.'s speech is immature, and even though he appears to know many words, he experiences difficulty in formulating them into sentences. He has particular difficulty in comprehending ambiguous sentences, and interprets language extremely literally. A recent example of this occurred when his parents received a letter from his school reporting that a teacher had brought head-lice into the school. He apparently believed that the teacher in question had arrived with a sack full of these creatures. In a similar vein, in response to being told that his computer had a virus, he taped up the cracks around the door of the room in which the computer was located. J.G. is unwilling to celebrate his birthday until the exact time of his birth on the day, and he always insists that a birthday cake (for Jesus) is produced on Christmas Day.

Since his earliest childhood, J.G. has favoured dark colours, particularly blue and purple. His family have reported early incidents during which he attempted to "dye" clothes blue, and even attempted to paint the family dog blue. Within the family home, all attempts are made to provide J.G. with a stress free environment. His bedroom is painted purple and black, all of his clothes except his football kit are blue, and the family car is blue with a purple interior. J.G. enjoys painting model soldiers, and because all the figures are painted blue, black and purple, his hobby is a means by which his colour obsession can be satisfied.

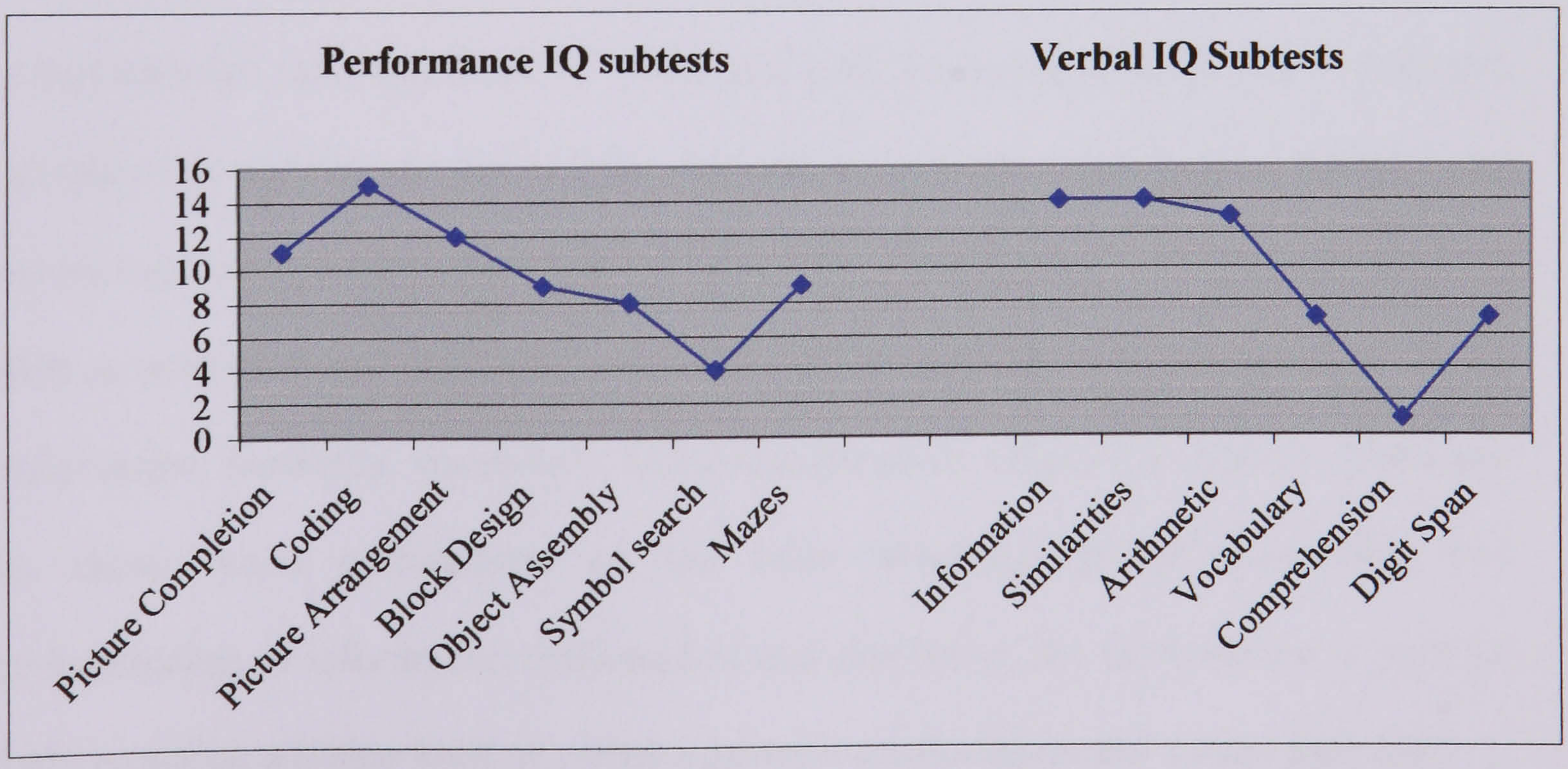
J.G. has very strong reactions to certain classes of sensory input. For example, he reports pain in his eyes ("hot eyes") in response to bright colours, and exposure to such colours sometimes results in hyper-excitability and nausea. He dislikes all types of light and does not have lights in his bedroom. Although his tolerance for certain colours has improved with age, he continues to carry his sunglasses around with him, even indoors. The behavioural consequences of J.G.'s visual processing difficulties have been debilitating, and have sometimes been difficult to manage For example, he is unable to sleep in a room or travel in a car that is not blue, purple or black in colour.

J.G. prefers to eat food that is white or has little colour, such as cottage cheese, potatoes, bread and white lettuce. Whilst his tolerance for coloured food is increasing over time, he is still unable to tolerate more than two colours on a plate, especially if they have a strong smell. Thus, for example, whilst he can eat cottage cheese with spinach or baked beans, he will become nauseous if all three are presented together.

PSYCHOMETRIC DATA AND ACADEMIC HISTORY

An initial assessment, using the Weschler Intelligence Scales for Children (WISC) (3rd edition) showed that Full Scale IQ was 104, Performance IQ was 105 and Verbal IQ was 102. Although these scores were within the normal range, Figure 6.1 illustrates the wide variation in levels of performance across the different subtests.

Figure 6.1: J.G.'s score on the WISC



From Figure 6.1 it can be seen that J.G. shows a very uneven pattern across different cognitive domains. Across performance subtests, he shows particular strengths in respect of picture completion (identifying missing parts of pictures) and coding (transcribing a digit symbol code as quickly as possible), whilst he shows particular weaknesses on symbol search (deciding if target symbols appear in a row of symbols and marking either yes or no accordingly). He demonstrates reasonable performance on tasks measuring perceptual organisation (picture completion and arrangement, block design, object assembly). However, he shows a disjointed pattern on tasks measuring processing speed, with excellent performance on coding but weaker performance on the symbol search task.

Across verbal subtests, he shows good performance on information (oral trivia style questions) and similarities (explaining how two different things, like horses or cows or concepts like hope and fear, could be alike), but demonstrates weaknesses on comprehension (oral questions of social and practical understanding) and vocabulary (giving oral definitions for words). He shows average performance across tasks measuring freedom from distractibility (attention, concentration and working memory) such as arithmetic and digit span tasks. His verbal comprehension (as measured by the information, similarity, vocabulary, and comprehension sub-tests) is uneven. Although he shows good performance on the tasks assessing general knowledge and understanding of information (information and similarity), his performance is poor on tasks requiring a higher level of verbal explanation (vocabulary and comprehension).

Although J.G.'s global IQ score is within the normal range, he attends a school for children with special needs. J.G.'s parents believe that his sensory difficulties are the main barrier to being able to cope with mainstream school life, but it seems likely that his uneven intellectual skill profile, especially his poor language comprehension, would create difficulties were he to be educated within the mainstream education system. Within his special needs school, J.G. receives support from the Speech and Language Services and the Autism Spectrum Disorders (ASD) department.

J.G.'s social skills are unusually good for a child with an autistic spectrum disorder, and his school report notes that he is "a friendly, helpful boy who is popular with his peers". Whilst certain situations cause J.G. anxiety, his teacher notes that "he has worked at using coping strategies and has improved in self-confidence". J.G. also enjoys the company of adults, and recently acted as a specialist consultant on an EU funded research project investigating sensory processing abnormalities in children with autism.

SENSORY ABNORMALITIES

J.G's mother provided a wealth of anecdotal evidence for his sensory abnormalities across perceptual domains. For example, J.G. cannot tolerate strong smells, such as those of washing powder and glue. Indeed, he actively refuses to wear clothes that have been washed with perfumed soap powder. He likes the smell of his own body and is unhappy when his bedding is changed. His auditory difficulties include a marked intolerance to the sound of vacuum cleaners, and he responds to such sounds by covering his ears and crouching down. He finds physical contact highly aversive, and consequently refuses to attend appointments with the family dentist or hairdresser.

Generally, he avoids situations where he experiences sensory overload, and has yet to fully participate in the celebrations for a family Christmas.

Although J.G.'s mother has always been aware of his sensory difficulties, these had never been formally investigated. J.G.'s sensory profile was therefore assessed using a test developed by Dunn (1999) called the Sensory Profile. This test provides a standard method to measure a child's sensory processing, and to profile the effect of sensory processing on functional performance in the daily life of the child. The sensory profile is a judgement-based questionnaire for caregivers in which each item describes the child's response to a range of sensory experiences. The caregiver who has daily contact with the child (in this case J.G.'s mother) completes the questionnaire, which measures the frequency with which target behaviours occur (e.g. always, frequently, occasionally, seldom, or never). The Sensory Profile consists of 125 items grouped into three main sections: sensory processing, modulation, and behavioural and emotional responses.

Research on the Sensory Profile took place between 1993 and 1999, and included more than 1,200 children aged between three and fourteen. The sample of children without disabilities included 1,037 children aged between three and ten years that were not receiving special education and were not taking regular medication. Norms for disabled children were derived from children with ADHS (n=61, ages, 3-15), Autism/Pervasive Development Disorder (N=32, ages, 3-13), Fragile X-syndrome (n=24, ages 3-17), as well as children with behavioural and learning disabilities. Researchers defined a classification system by determining cut scores for each of the sections and factor raw score totals. The classification system, derived from the research sample of children without disabilities, describes the child's sensory processing for each section and factor as either (a) typical, (b) probable difference, or (c) definite difference.

Each section of J.G.'s Sensory Profile was examined individually, and was compared to the norms from children without disabilities and children with autism (Sensory Profile Manual; Dunn, 1999).

Sensory Processing Section

The results from this section provide data on sensory processing abnormalities in the different sensory modalities. J.G.'s scores, together with norms for children without disabilities and children with autism are shown in table 6.1. Scores that achieve criteria for sensory abnormality are marked with a star.

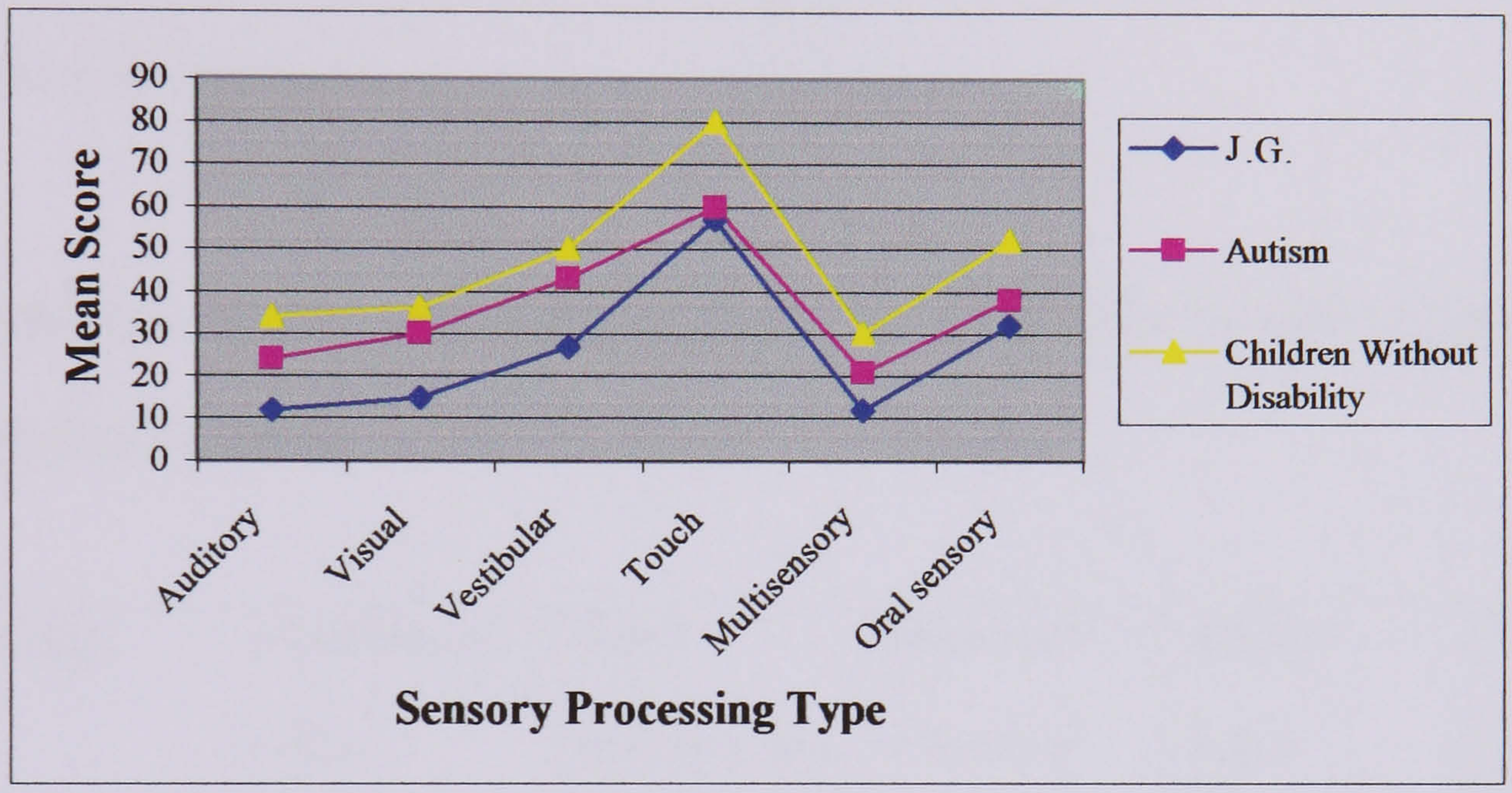
Table 6.1: Means of children without disability and autism across the sensory Measures

Group	Auditory (max=40)	Visual (max=45)	Vestibular (max=55)	Touch (max=90)	Multi Sensory (max=35)	Oral (max-60)
Children Without Disability	34	36	50	80	30	52
Autism	24*	30	43*	60*	21*	38*
J.G.	12*	15*	27*	57*	12*	32*

*=Atypical performance

Table 6.1 shows that J.G.'s scores are consistently lower (showing more variation from typical performance) than the normative data across modalities. This is further illustrated in figure 6.2 below.

<u>Figure 6.2: J.G's performance in comparison to controls across different types of sensory processing.</u>



J.G. shows the greatest variation from the norms in his response to auditory, visual and vestibular processing. His scores for touch, multisensory and oral sensory processing are much closer to those of norms derived from children with autism.

Modulation Section

This section reflects the child's regulation of neural messages through facilitation or inhibition of various types of responses. Modulation is broken down into five areas of sensory modulation: sensory processing related to endurance/tone (measuring the child's ability to sustain performance); modulation related to body position and movement (measuring the child's ability to move effectively); modulation of movement affecting activity level (measuring the child's demonstration of activeness); modulation of sensory input affecting emotional responses (measuring the child's ability to use body senses to generate emotional responses); and modulation of visual input affecting emotional responses and activity level (measuring the child's ability to use visual cues to establish contact with others).

J.G's scores on these measures were again compared to those of the two groups and are shown in table 6.2.

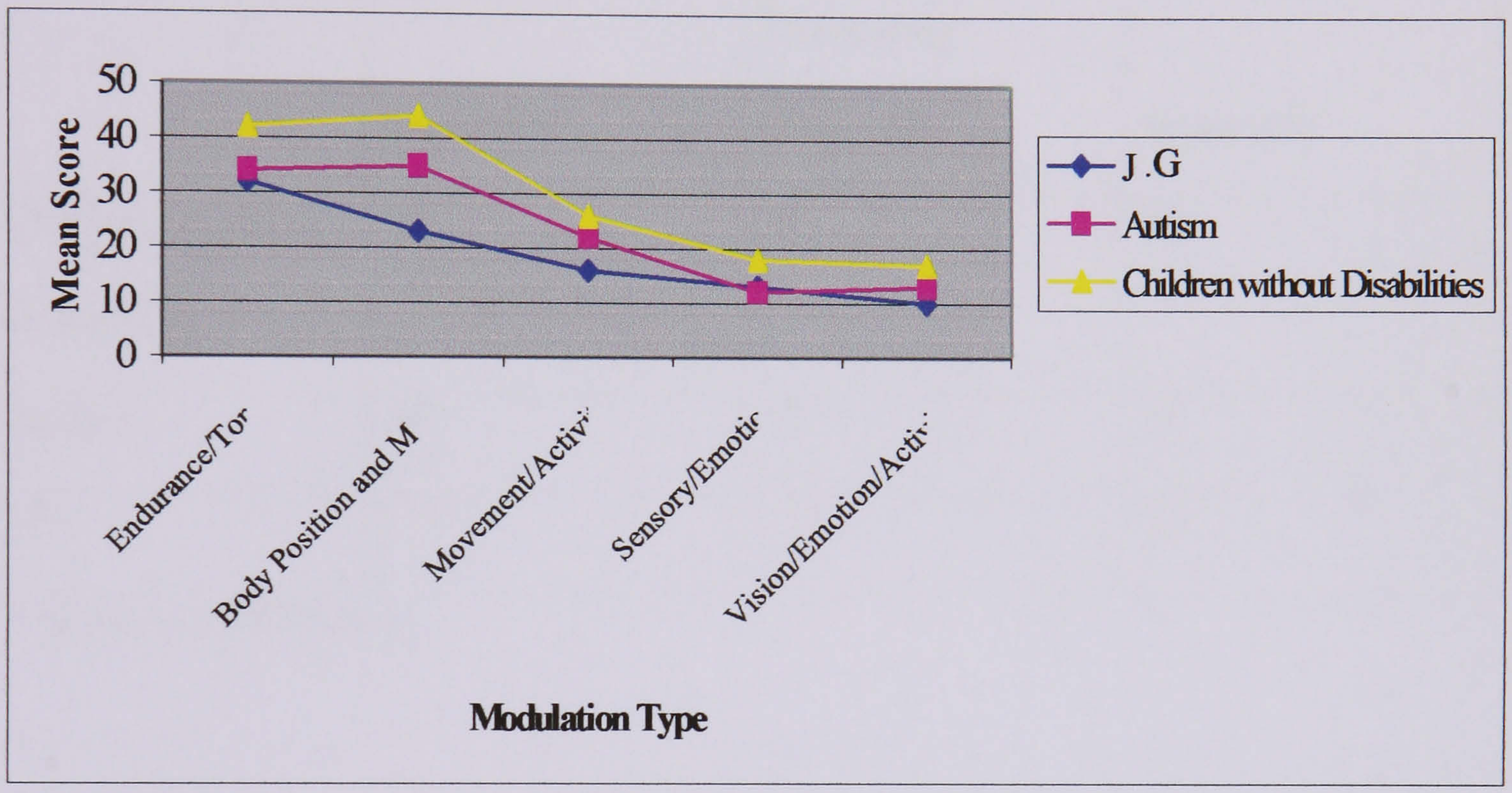
Table 6.2: Mean scores of children without disabilities and autism across modulation types

Group	Endurance/ Tone (max=45)	Body position and Movement (max=50)	Movement Affecting Activity Level (max=35)	Sensory Input Affecting Emotional Response (max=20)	Visual Input Affecting Emotional Responses and Activity Level (max=20)
Children Without Disability	42	44	26	18	17
Autism	34*	35*	22	12*	13
J.G.	32*	23*	16*	13*	10*

***=atypical performance**

This pattern of results is shown in figure 6.3, where it can be seen that J.G.'s scores across measures fall below those of the other two groups. J.G. shows the most variation from the two groups on modulation related to body position and movement.

Figure 6.3: J.G's performance in comparison to controls across different types of modulation



Behavioural and Emotional Responses

This section reflects the impact of sensory processing on behaviour. The measures are broken down into emotional/social responses (items indicating the child's psychosocial coping strategies), behavioural outcomes of sensory processing (indicating the child's ability to meet performance demands), and items indicating the threshold for response (indicating the child's level of modulation). J.G.'s scores on these measures are shown in table 6.3.

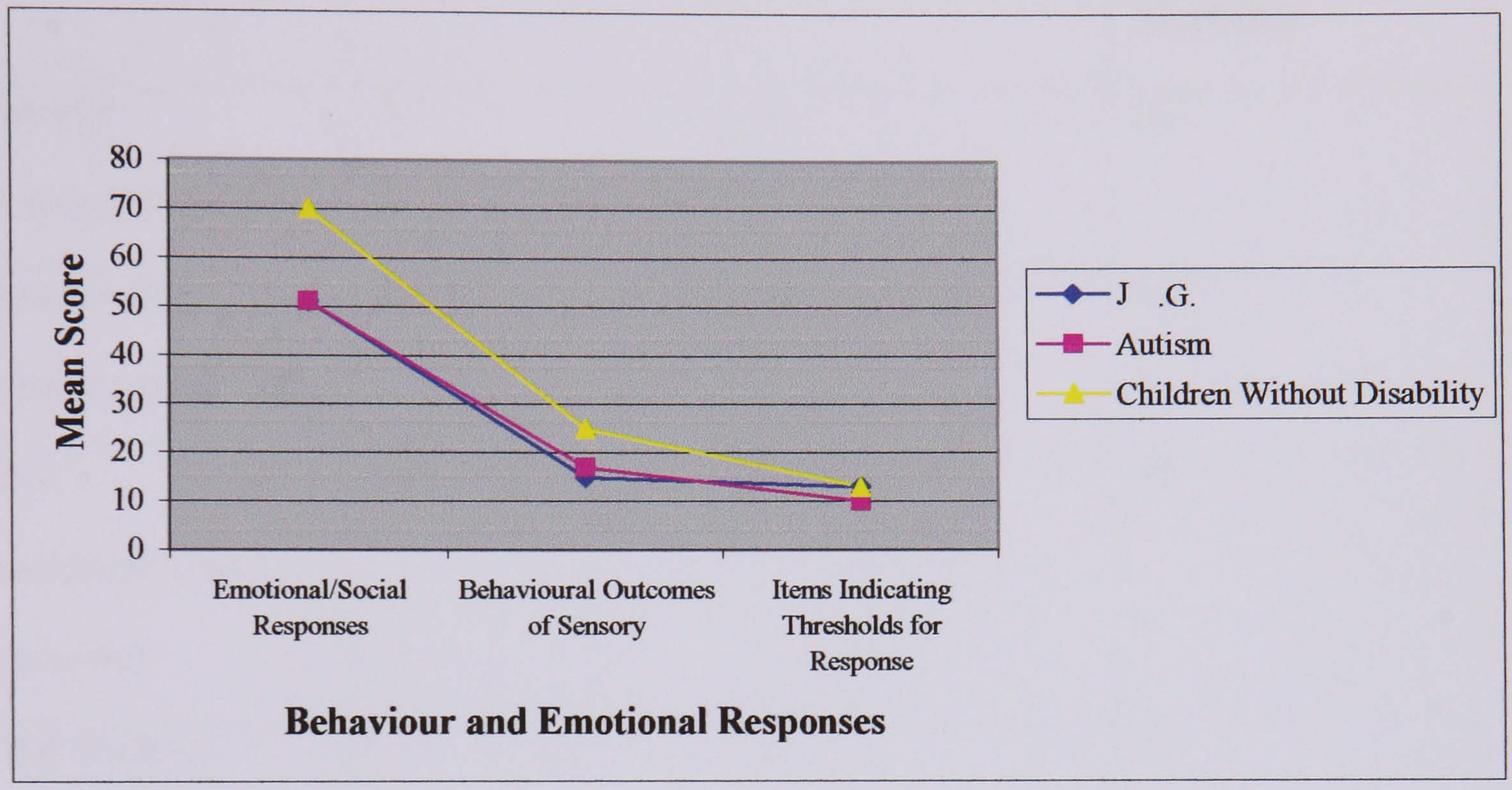
Table 6.3: Mean scores of children without disabilities and with autism for behavioural and emotional responses

Group	Emotional/Social Responses (max=85)	Behaviour Outcomes of Sensory Processing (max=30)	Items indicating Thresholds for Response (max=15)
Children without disabilities	70	25	13
Autism	51*	17*	10
J.G.	51*	15*	13

*=atypical performance

J.G.'s scores for emotional/social responses and behavioural outcomes of sensory processing met the criteria for atypical performance, although they were consistent with those of other children with autism. On the items indicating thresholds for response, J.G. showed no abnormalities and his score did not differ from norms derived from the typical sample. This is illustrated in figure 6.4.

Figure 6.4: J.G's scores in comparison to controls for behaviour and emotional responses



The Nine Different Factors on the Sensory Profile

Items on the Sensory Profile unite to form nine meaningful groups or factors. These are Sensory Seeking, Emotionally Reactive, Low Endurance/Tone, Oral Sensory Sensitivity, Inattention/Distractibility, Poor Registration, Sensory Sensitivity, Sedentary and Fine Motor Perceptual. The factors identify items that characterise children by their responsiveness to sensory input (for example, overly responsive or under-responsive). J.G.'s scores, together with norms, are shown in table 6.4

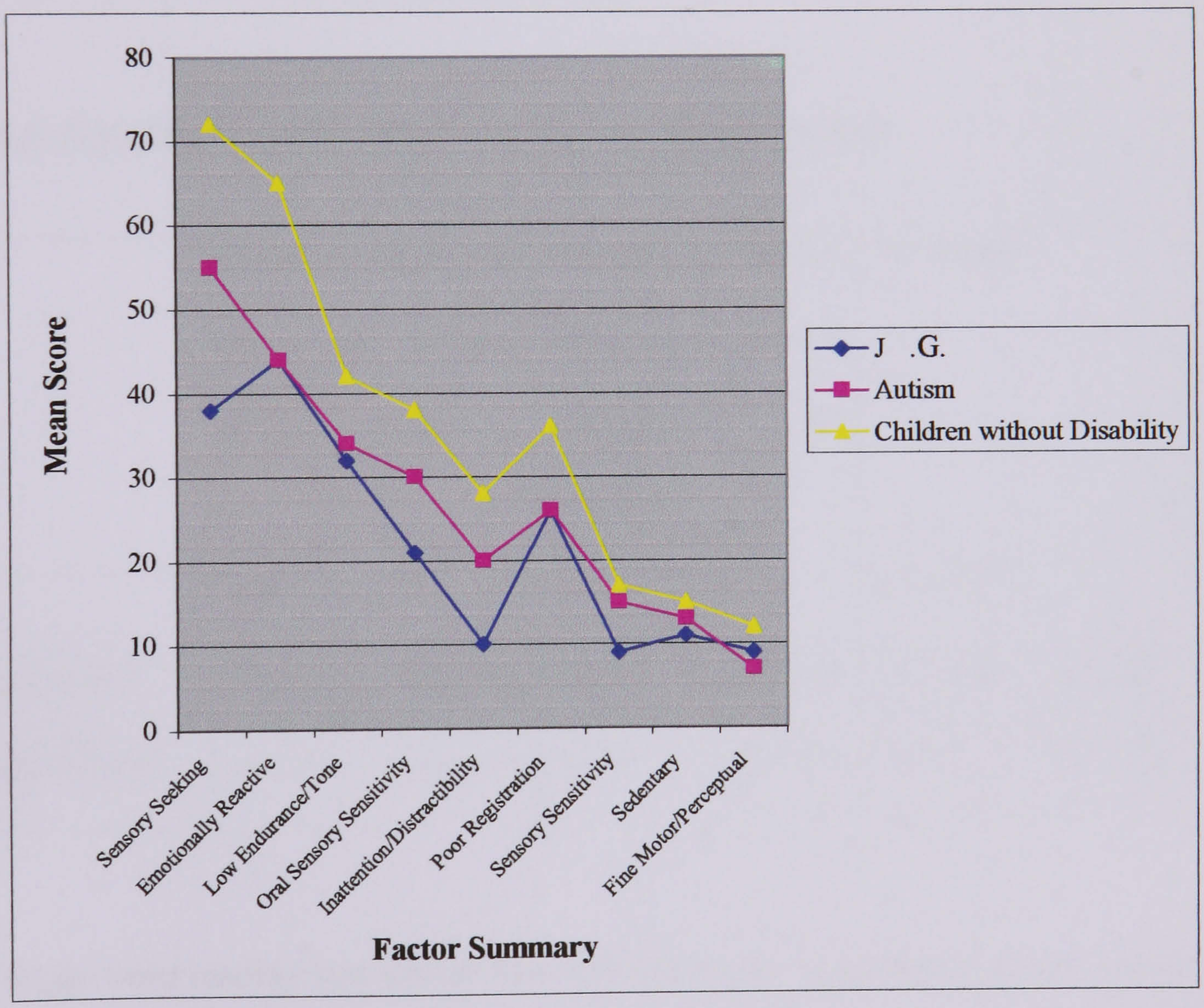
Table 6.4: Mean scores of children without disabilities and the children with autism across the nine factors.

Factors	J	Autism	Children Without Disability
Sensory Seeking (max=85)	38*	55	72
Emotionally Reactive (max=80)	44*	44*	65
Low Endurance/Tone (max=45)	32*	34*	42
Oral Sensory Sensitivity (max=45)	21*	30	38
Inattention/Distractibility (max=35)	10*	20*	28
Poor Registration (max=40)	26*	26*	36
Sensory Sensitivity (max=20)	9*	15	15
Sedentary (max=20)	11	13	13
Fine Motor/Perceptual (max=15)	9	7*	12

* Atypical Performance

As can be seen from the above table, J.G.'s scores fall below those of the other two groups on nearly all the factors indicating atypical performance across the sensory profile. J.G. shows the widest variation from the children with autism on the sensory seeking, oral sensory sensitivity, inattention/distractibility and sensory sensitivity factors. This profile is shown in figure 6.5.

Figure 6.5: J.G's performance compared to norms across the nine factors of the sensory profile



INVESTIGATION OF THE IMPLICATIONS OF SENSORY PROCESSING ABNORMALITIES IN THE VISUAL MODALITY IN J.G.

In 2005, J.G. completed the series of studies, described in chapters two and three, that tested single word reading (experiment one), comprehension of written text (experiment three), and detection of visual discrepancy (experiment four) with and without a colour overlay. The methods for these experiments are described in chapters two and three, but for ease of comparison, J.G.'s performance scores are presented together with those of the children who participated in these previously described studies in the next section. Table 6.5 shows the scores for the rate of reading test.

Table 6.5: Data for J.G. and controls on the rate of reading task

Group	Number of Words Read per minute with an overlay	Number of Words Read per minute without an overlay	% Faster
J.G.	70	52	34.60%
Autism (N=19)	84.63 (26.84)	74.74 (27.34)	16.32% (18.42)
Controls (N=19)	64.19 (26.35)	69.69 (30.59)	-5.84 (13.35)

J.G.'s single word reading was slower than that of the two comparison groups without an overlay. However, his performance was greatly facilitated by the overlay, and his percentage increase in reading speed was one standard deviation above the mean for the autism group. The members of the control group did not increase their reading speed with an overlay on this experiment. J.G.'s performance scores on the comprehension task (SCLOP; Baddeley et al. 97; experiment three) are shown, together with data from the children who participated in experiment three, in table 6.6.

Table 6.6: Data for J.G. and controls on the comprehension task.

Group	Number correct with an overlay (max=40)	Number Correct without (Max=40)	Time taken with an overlay (seconds)	Time taken without an overlay (seconds)	Percentage Faster
J.G	40	40	358.37	450.90	25.8%
Autism (N=17)	38.2 (2.4)	38.3 (2.5)	181.90 (83.99)	201.97 (10.45)	6.16% (16.45)
Controls (N=17)	38.8 (2.2)	38 (4.2)	239.92 (68.35)	238.96 (74.05)	-2.74% (18.66)

J.G.'s percentage increase in speed on the comprehension test when using an overlay was one standard deviation above the mean for the autism group. The control group did not increase their reading speed with an overlay on this experiment. Interestingly, given J.G.'s poor performance on the comprehension subtest of the WISC, he showed excellent comprehension skills on this task and made no errors, although he was much slower at completing the task than the other participants. The SCLOP requires the subject to read sentences and make a judgement about whether they are true or false, whereas the comprehension subtest from the WISC involves oral questions of social and practical understanding.

J.G.'s performance scores for the non-verbal discrimination task (experiment four) are shown, together with data from the children who participated in experiment four, in table 6.7.

Table 6.7: Data for J.G. and controls on the visual cognition task.

Group	Number Correct with an overlay (max=30)	Number Correct without an overlay (max=30)	Time taken with an overlay (Seconds)	Time taken without an overlay (Seconds)	Percentage faster with an overlay
J	30	30	116.63	110.33	-5.70%
HFA (N=13)	28.92 (1.55)	28.62 (1.45)	101.99 (48.72)	124.62 (57.44)	12.85% (26.83)
TD (N=13)	26.62 (3.80)	26.23 (3.70)	157.45 (83.53)	132.22 (88.20)	-26.09% (38.63)

As can be seen from table 6.7, J.G. performed at ceiling on this task with and without overlays, and was therefore unable to show any improvement in accuracy with an overlay. However, this finding is unsurprising given J.G.'s level of performance on the picture completion subtest from the WISC. On both the picture completion and this visual cognition tasks, subjects are required to compare similarities and differences across stimuli. Clearly J.G.'s sensory processing abnormalities do not impact on his capacity to carry out detailed analyses of black and white non-linguistic visual stimuli.

Indeed, given that J.G. was slower on the task when using an overlay, it may be that colour overlays are distracting in this context.

COLOUR CHOICE AND VISUAL STRESS

In studies using colour overlays, participants are required to record details of visual stress symptoms. J.G.'s visual stress symptoms, together with details about his overlay choices are shown in table 6.8.

Table 6.8: J.G's overlay choice and visual stress symptoms across overlay tasks.

Presented stimuli	Overlay type	Overlay colour	Reported visual stress symptoms
Single words	Double	Purple/Purple	Letters moved and blurred Page too bright and painful to see
Written Text	Single	Purple	Page too bright and painful to see
Non-verbal task	Double	Purple/Blue	Page too bright and painful to see

The results from these studies showed that J.G. showed the greatest benefit from a self-selected colour overlay on the single word reading task. It is of interest that whilst he reported that the page was too bright and painful to look at for all of the presented stimuli, only the text with single words appeared blurred and moved around. The words in this particular passage of text were smaller and closer together than those used in the comprehension study. This may have contributed to J.G.'s perception of their visual distortion.

After completing these three experiments, J.G. was supplied with purple and blue overlays for use in school. When tested seven months later, his raw score on the Suffolk Reading test (Hagley, 1987) increased from 19 to 33, and his raw score on the NFER7 maths test (NFER-Nelson, 2002) increased from 23 to 26. His teacher's report suggests that he has been better able to achieve his academic goals when using his overlays.

EXPERIMENTAL STUDIES

An important question that has not been systematically investigated is whether colour obsessions noted in autism impact on colour processing. The studies reported in this thesis have shown that, whilst many children with autism benefit from the use of a colour overlay, many aspects of colour cognition do not differentiate children with and without autism. Indeed, the only significant difference between intellectually able children with autism and those with typical development related to their perception of category boundaries, and it was argued that this is more likely to reflect linguistic rather than perceptual factors. It may then be the case that colour overlays are beneficial for children with autism whose sensory processing abnormalities are relatively minor. Both parent and teacher reports, together with the findings from the Sensory Profile, suggest that for J.G. these difficulties are particularly debilitating. An important research question concerned the extent to which his performance on colour processing tasks would differ from that of other able autistic children who did not show colour obsessions. In an attempt to address this question, J.G. completed the tests described in chapters four and five (experiments five to eleven). In the following sections his data is compared with that of thirteen HFA (mean age 10 years 9 months) and thirteen TD (mean age 11 years 2 months) participants who had completed the experiments. The methods for these experiments are described in chapters four (experiments five, six, seven and eight) and chapter five (experiments nine, ten and eleven).

An initial assessment, using the City University Colour Test ((3rd edition; Fletcher 1998) and Ishihara Colour vision test (Ishihara, 1970) (see chapter two) was carried out. This showed that J.G., like the participants with HFA and TD who participated in the group studies, showed no abnormalities.

Table 6.9: Scores of J.G and controls on the City/Ishihara colour tests

	City University Test (max score=16)	**Ishihara (max score=38)**
J.G.	16	37
HFA (N=13)	15.92 (sd 0.28)	36.33 (sd 3.05)
TD (N=13)	15.91 (sd 0.29)	35.54 (sd 3.01)

Colour comprehension and naming: J.G. achieved the maximum score of eleven for both colour name production and colour name comprehension utilising red, blue, green, yellow, orange, pink, purple, black, white, brown, and grey colour chips.

COLOUR DISCRIMINATION

This task (described in chapter four, experiment six) involved selecting the odd one out from three colour patches within the red, yellow, green and blue categories. The perceptual distance effect was tested in three experimental conditions (small, medium and large). As large interval distances (2.5 & 10) within the yellow and red colour categories are not within category exemplars, separate analyses were carried out on these. Table 6.10 shows the means and standard deviations for identification across experimental conditions for blue and green.

Table 6.10: J.G.'s and controls' scores for the total number of colours correctly identified in the three experimental conditions (small, medium and large perceptual distances) in the blue and green categories.

Group	Small blue/green (Max=4)	Med blue/green (Max=4)	Large blue/green (Max=4)
J.G.	3	3	3
Controls (HFA and TD) (N=26)	2.31 (1.12)	3.04 (0.59)	3.77 (0.51)

In experiment six (chapter four) no significant difference in levels of performance between participants with HFA and TD had emerged, although there had been a significant effect of condition, with increasingly accurate identification as perceptual distance between target and distractor patches increased. As can be seen from table 6.10, J.G.'s scores were the same in all three conditions, and his score for the large condition was one standard deviation below the control group mean. This is illustrated in figure 6.6.

Figure 6.6: J.G.'s performance in comparison to controls across the three intervals (small, medium and large) for the blue and green categories.

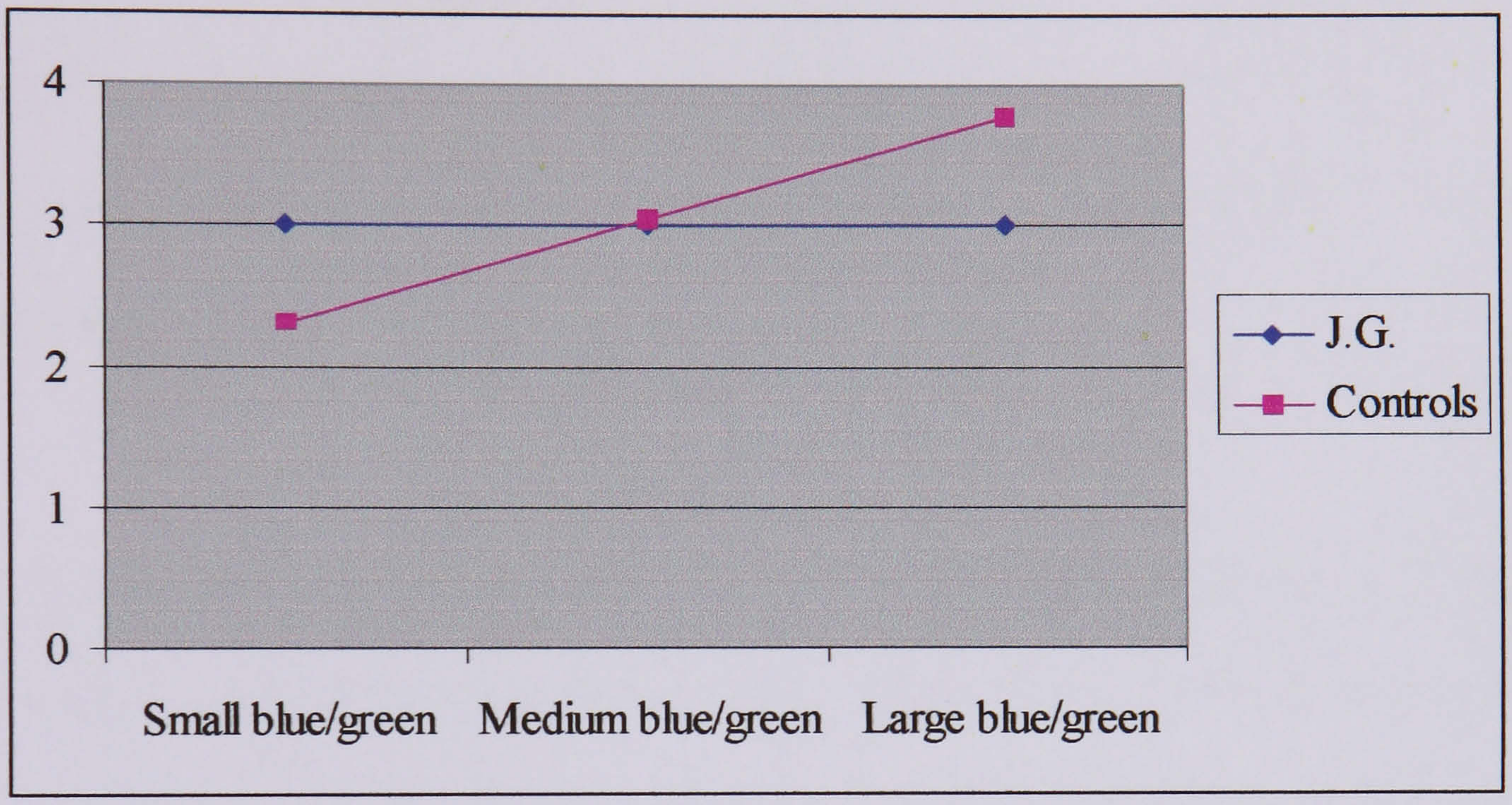


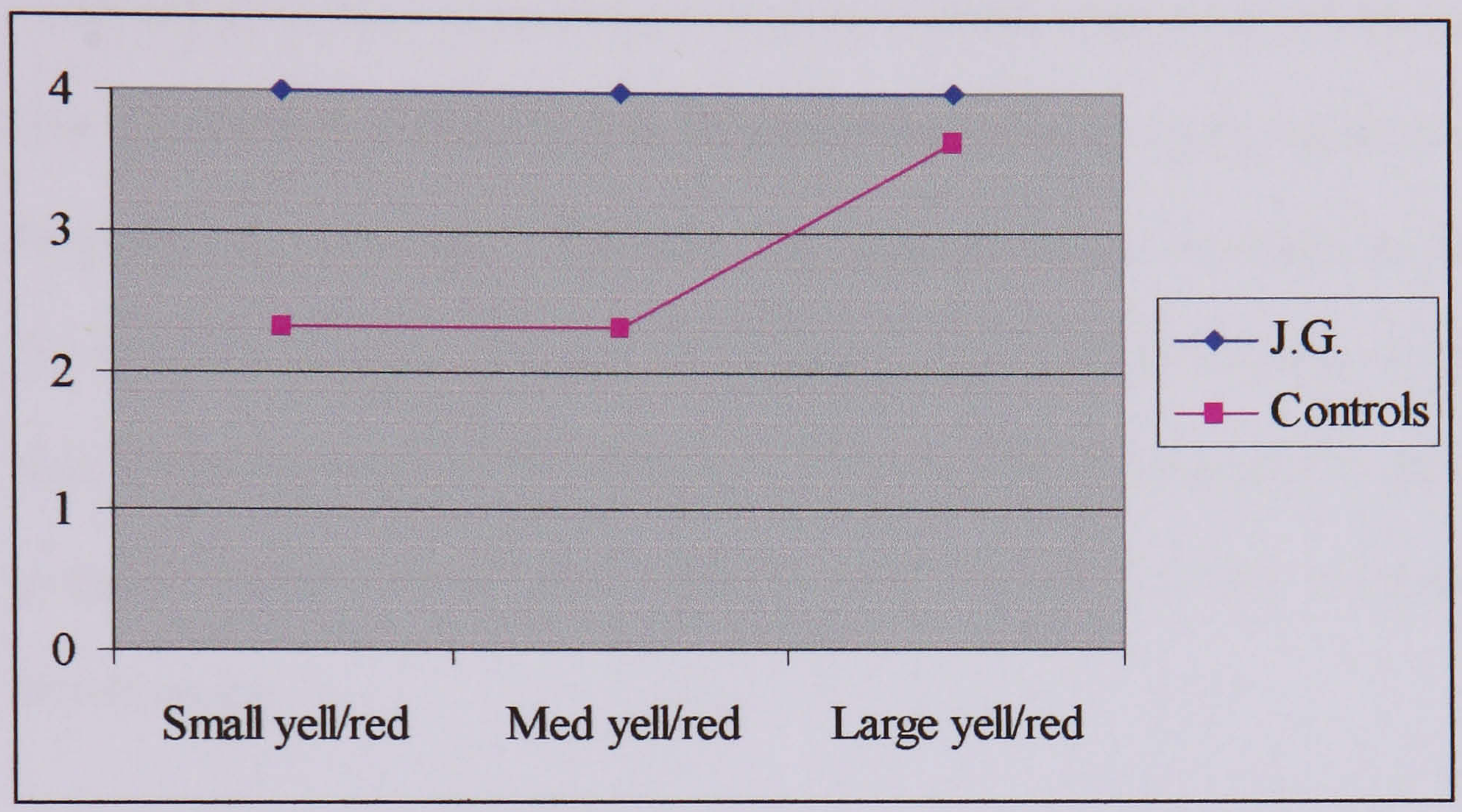
Table 6.11 shows the means and standard deviations for identification across experimental conditions for the yellow and red categories.

Table 6.11: J.G.'s and the controls' means and SD's for the total number of colours identified in the three experimental conditions (small, medium and large perceptual distances) in the yellow and red categories.

Group	Small yellow/red (Max=4)	Med yellow/red (Max=4)	Large yell/red (Max=4)
J.G.	4	4	4
Controls (HFA and TD) (N=26)	2.31 (1.29)	2.31 (1.29)	3.65 (0.56)

In experiment six (chapter four) a different pattern of performance with red/yellow patches in comparison to blue/green patches had been seen. Participants had shown no increase in correct identifications in the medium compared to the small condition, but had been very good at identifying the category boundary chips in the large condition. As table 6.11 shows, J.G. performed at ceiling in all three conditions, and his scores for the medium and large conditions were one standard deviation above the control group means. This is further illustrated in figure 6.7 overleaf.

<u>Figure 6.7: J.G.'s performance in comparison to controls across the three intervals (small, medium and large) for the red and yellow categories.</u>



Inspection of J.G.'s individual data for the discrimination study showed that he made overall correct same/different discriminations for 87% of the colour pairs. Only three interval pairs were incorrectly classified, and these were all drawn from the blue range, with one at each size interval (2-5, 2-5-7-5, 2-5-10). Thus, whilst J.G. correctly identified all red, yellow, and green stimuli, he only identified 50% of the blue stimuli correctly. This meant that his identification performance was significantly better than that of controls for all colours except blue where his performance was significantly worse. It therefore appears that his colour sensitivities and obsessions have implications for his perceptual processing of colours. More specifically, he shows superior discrimination of colours that he dislikes, and actively avoids and inferior discrimination of his preferred colour blue. This will be discussed further.

The results from experiment seven (reported in chapter four) showed that intellectually unimpaired children with autism have sharper category boundaries than TD controls. Although this finding was consistent with predictions drawn from the RG theory (Plaisted, 2001) described in the introduction, the account was rejected as it assumes enhanced perceptual processing in autism, and this was not in evidence in the sample that were tested. Instead it was proposed that sharp category boundaries reflect literal language use in autism. J.G. has a very strong tendency towards literal language use, but also shows some evidence of enhanced perceptual processing, at least for colours that he finds aversive. The following section ascertains whether J.G. possesses different category boundaries to other children with autism, as well as those with typical development.

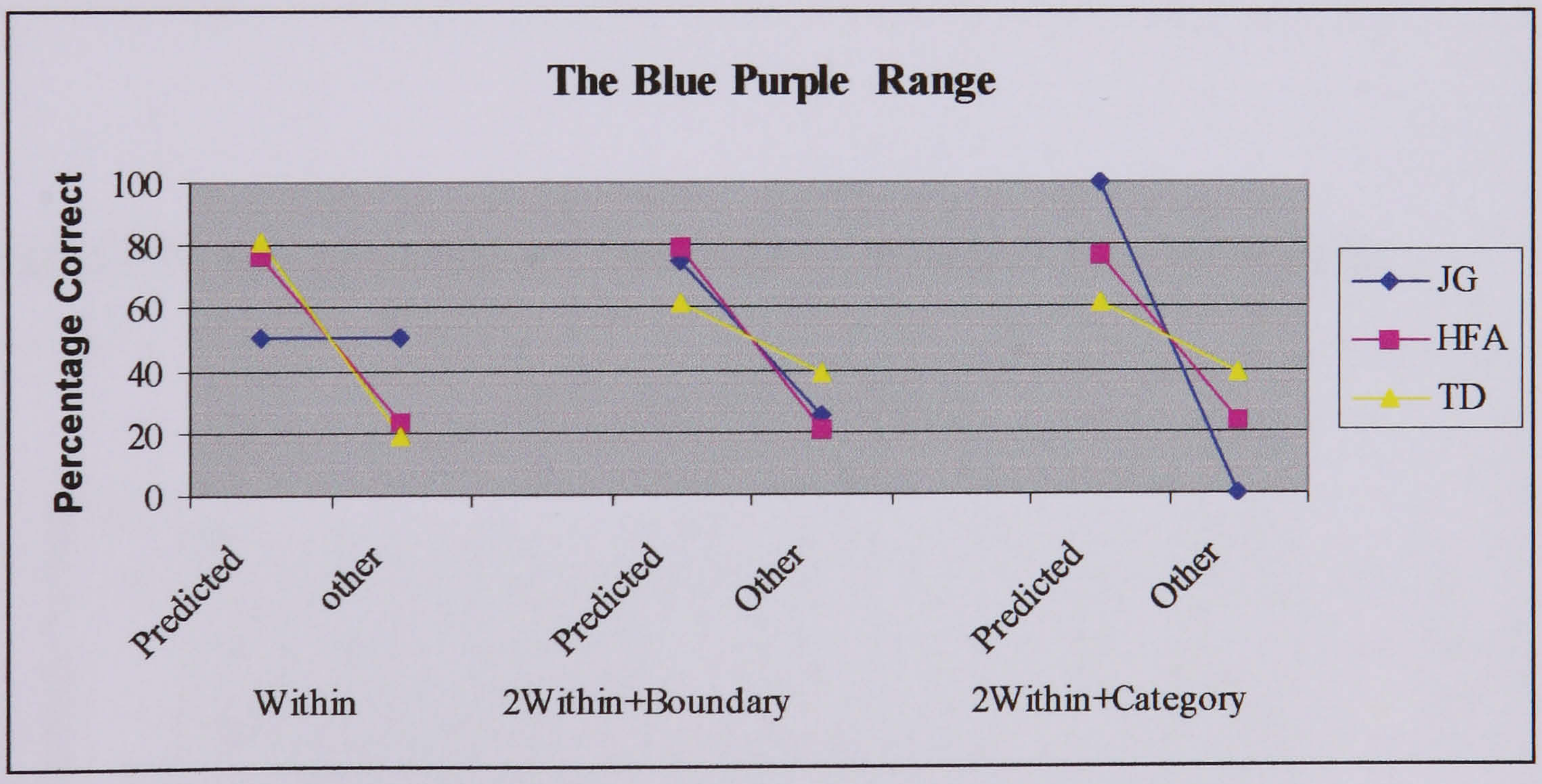
COLOUR CATEGORISATION

Colour chips were presented in triads in either the purple/blue or blue/green range, and participants were required to choose the chip that was most different. These triads comprised three chips within category (condition one), two chips within category and one boundary chip (condition two), or two chips within category and one from a different category (condition three). As was the case for experiment seven, the analysis was carried out on predicted chip choice scores. The predicted chip for condition one was the one nearest to the next category boundary, for condition two the boundary chip was predicted, and for condition three the different category chip was predicted. Table 6.12 and figure 6.8 shows the percentage scores for J.G. and controls across the three conditions in the blue/purple range.

Table 6.12: Percentage scores for predicted chip choice in blue/purple range for J.G. and controls

Group	All Within (%)		2Within+Boundary		2Within +Category	
	Predicted	Other	Predicted	Other	Predicted	Other
J.G	50	50	75	25	100	0
HFA	76.92	23.08	78.84	21.16	76.92	23.08
TD	80.76	19.24	61.53	38.47	61.54	38.46

Figure 6.8: J.G.'s and controls' performance across the blue/purple range

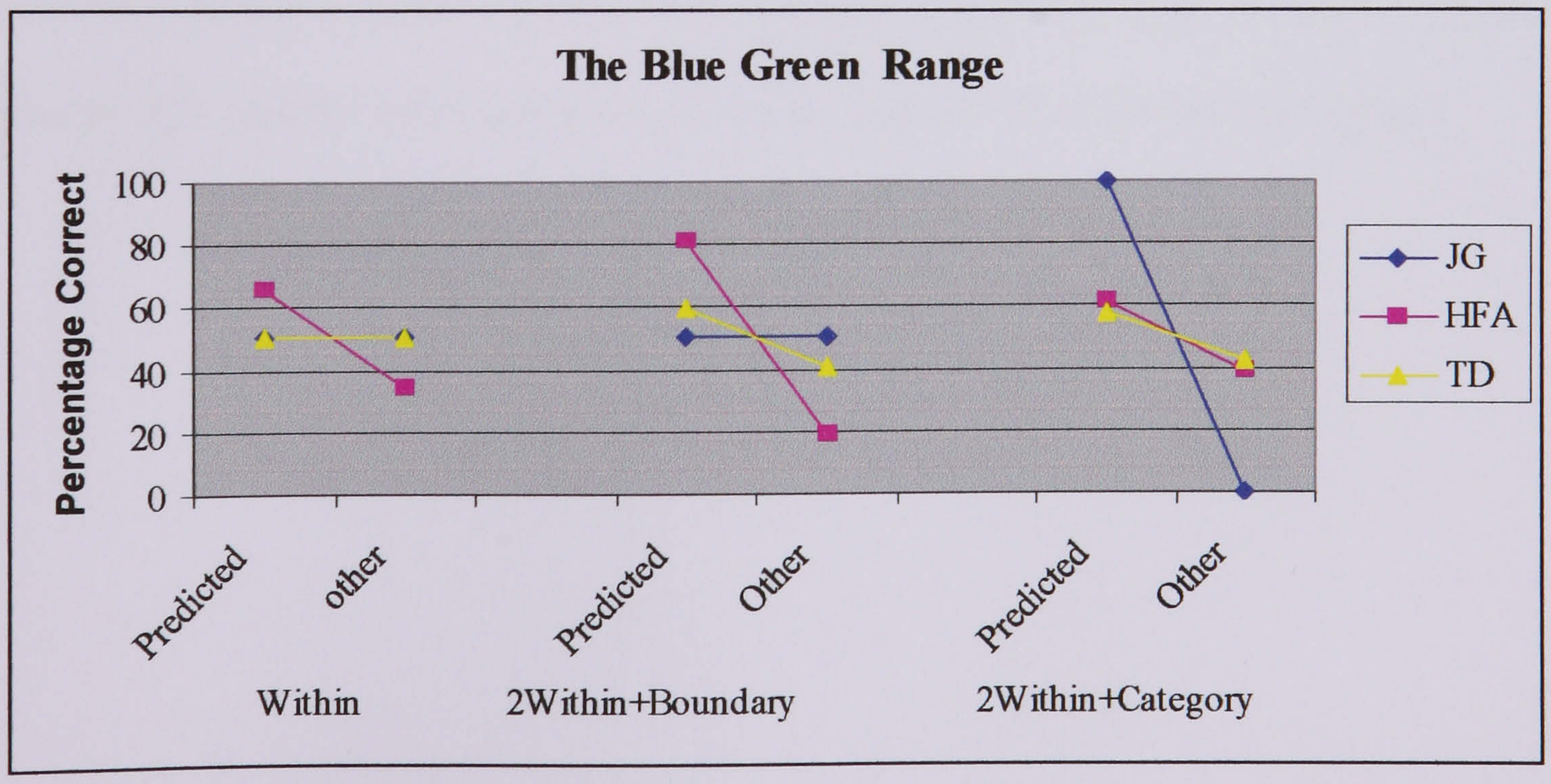


As can be seen, J.G. performed at ceiling on condition three where the predicted chip was in a different category. His performance was similar to that of the other participants with HFA on condition two which included a category boundary chip, suggesting that his category boundaries were sharper in this range. However, on condition one, where all chips were within category, he was as likely to select the unpredicted as the predicted chip. Table 6.13 and figure 6.9 show scores for blue/green stimuli.

Table 6.13: Percentage scores for predicted chip choice in blue/green range for J.G. and controls

Group	All Within (%)		2Within+Boundary		2Within +Category	
	Predicted	Other	Predicted	Other	Predicted	Other
J.G.	50	50	50	50	100	100
HFA	65.38	34.62	80.76	19.24	61.53	38.47
TD	50	50	59.61	40.39	57.69	42.31

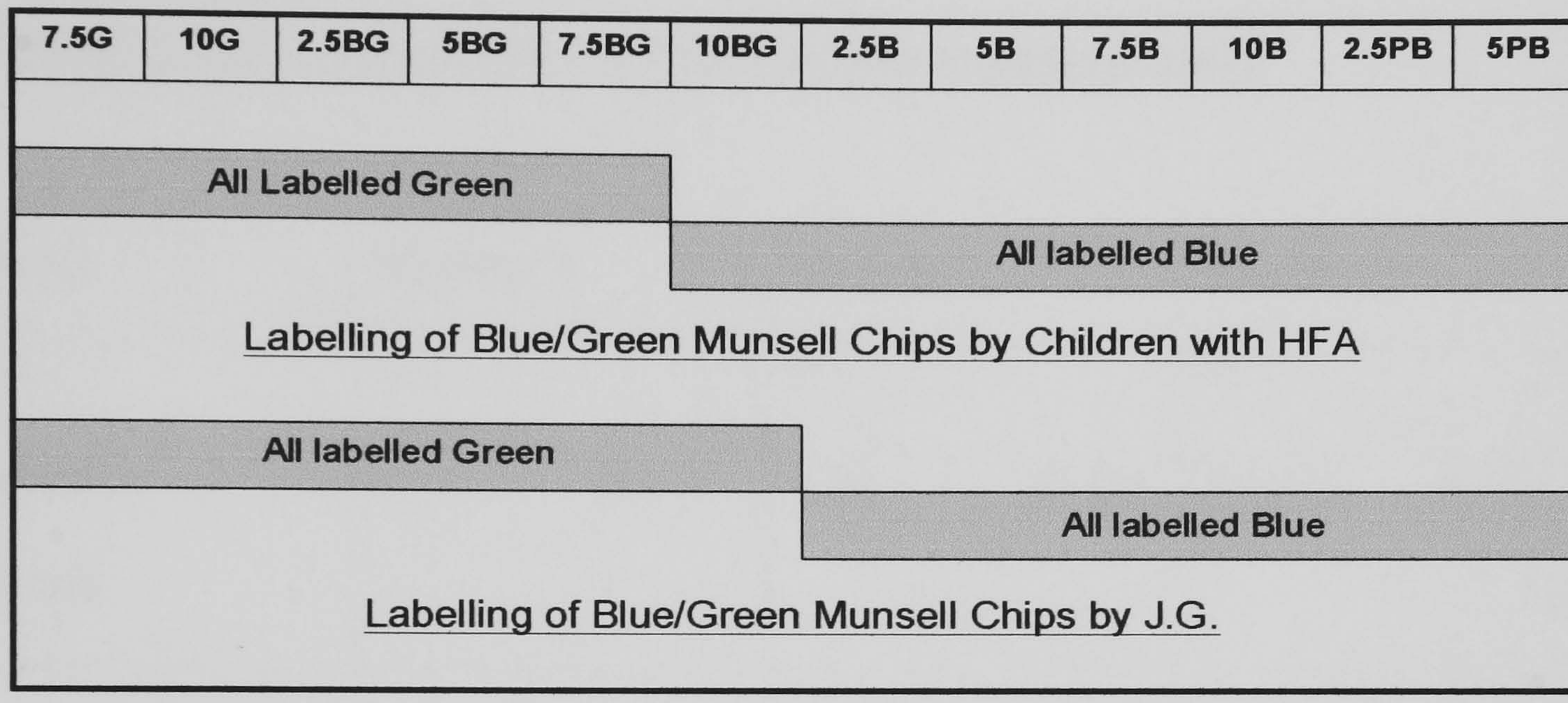
Figure 6.9: J.G.'s and controls' performance across the blue/green range.



It can be seen that J.G. shows a different pattern to both the HFA group and controls across the blue/green range. As was the case for the blue/purple range, he performed at ceiling on the condition where the predicted chips were in another category. Furthermore, he clearly did not perceive the category boundaries in this colour range in the same way as TD and HFA controls, and was as likely to choose the non-predicted chips as the predicted chips in the within and category boundary conditions. This finding was further investigated.

J.G. was presented with a series of chips from the blue/green range and was asked whether these were (a) blue, (b) green, or (c) neither. Similarly, he was shown chips from the blue/purple range and asked whether these were (a) blue, (b) purple or (c) neither. The findings from experiment seven, described in chapter four, had shown that for the majority of the twenty children with autism tested, 7.5 BG and 10BG and 5PB and 7.5PB represented category boundaries. Although J.G.'s perceived category boundary across blue and purple chips did not differ from that of the group, his boundary between green and blue was different. Details of chips named as green and blue by J.G. and the HFA group are shown in figure 6.10 on the following page.

Figure 6.10: Naming of Munsell blue/green colour chips by J.G. and children with HFA



This finding is consistent with those of the categorisation experiment in showing that J.G. possessed a wider green and a narrower blue category than the HFA group.

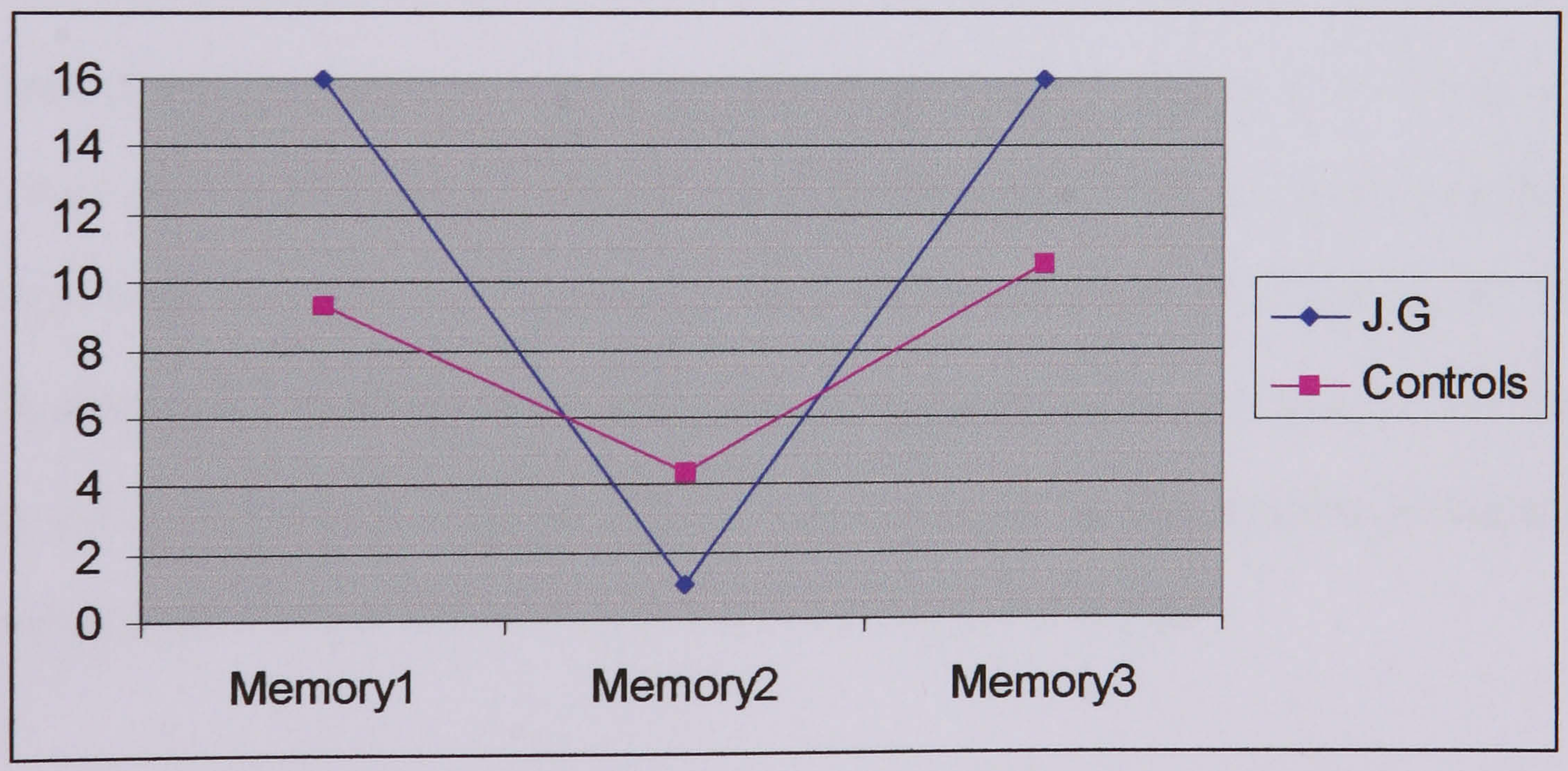
MEMORY TASKS

In these studies, J.G was tested on his ability to remember colours and colour names paired with animals. In memory condition one (chapter five, experiment nine), the retrieval of previously exposed animal/colour pairs could be facilitated by the use of verbal labels. However, in memory condition two (chapter five, experiment ten), test trials included colour patches that were all within category (red, blue, yellow and green), and a verbal encoding strategy (of colour name) would not facilitate performance. Memory condition three (chapter five, experiment eleven) paired animals and colour words and more explicitly tested verbal encoding. J.G.'s scores in comparison to controls are shown in table 6.14 and figure 6.11. As HFA and TD controls had not shown significant group differences in experiments nine, ten or eleven, their data are shown pooled.

Table 6.14: J.G's and controls' performance across memory tasks

Group	Memory 1	Memory 2	Memory 3
J.G.	16	1	16
Controls (N=26)	9.35 (5.00)	4.35 (2.56)	10.50 (4.95)

Figure 6.11: J.G's performance compared to controls on the memory tasks



As can be seen, J.G. showed a similar pattern of performance to controls, although his scores were more extreme. Indeed he scored at ceiling on memory conditions one and three, and only correctly identified one (red) stimulus in experiment two. Taken together, the findings suggest that he encoded very little of the perceptual information in the familiarisation trials and relied heavily on a verbal coding (colour word) strategy.

DISCUSSION

The findings from this case study represent the first systematic investigation of colour obsessions in autism. J.G.'s obsession with the colours blue, purple and black impacts on many aspects of his daily life, and the findings from the current studies suggest that it also influences his processing of colour information more generally. As previously suggested, colour obsessions are characteristic of some individuals with autism (White & White, 1987; Williams, 1999), although the behavioural and cognitive correlates of these are not well understood.

J.G. showed strong therapeutic benefits from using colour overlays, particularly when reading single words in a small font, and he reported a reduction in his symptoms of visual stress. However, it was also clear from the studies that he is able to perform at high levels on some visual processing tasks without overlays. For example, the WISC includes some tests with visual processing components, and J.G. attained either typical or good performance on these. On the experimental study that required participants to notice small changes in stimuli, J.G. performed very well indeed/

Inspection of J.G.'s WISC data showed low performance on the vocabulary subtest. However, he was able to name and comprehend all of the colours that he saw. The data from the categorisation and memory experiments suggests that his awareness of colour terms powerfully influences his perceptual processing of colours. For example, the categorisation study included a condition in which one of the three presented chips was taken from a different category. In this case, J.G. performed at ceiling both for the blue/green and blue/purple colours. Whilst HFA and TD children were significantly more likely to select different than within category chips, their discrimination scores were lower than those of J.G.. Furthermore, on the three memory tasks, J.G. was found to perform exceptionally well, in relation to controls, when a verbal labelling strategy conveyed an advantage. It may then be the case that one developmental outcome of debilitating sensory sensitivities is that there is a greater reliance on verbal labels than on perceptual information in memory. However, the data from the studies directly investigating colour perception provide strong evidence for enhanced perceptual processing of some, but not all, colours in J.G.

In the two phases of the experiment relating to perceptual colour distance, J.G. showed a very different pattern of performance to controls. Whilst HFA and TD controls had shown a steady increase in discrimination of odd-one-out blue/green chips as the perceptual distance between these and the two comparison chips increased, J.G. did not show this effect. Instead he performed at ceiling on all interval size conditions when chips were green, but showed poor discrimination performance when chips were blue. He also appeared to possess different category boundaries across blue/green in comparison to controls. When three within-category chips were shown in condition one of the categorisation experiment, the HFA participants were significantly more likely to select the chip that was nearest to the category boundary. However, J.G., like controls, was as likely to choose chips that were not near the category boundary. This effect was seen more strongly in condition two where the triad included a category boundary chip. The HFA group selected this chip 80% of the time and TD selected it 60% of the time.

However, again J.G. was equally likely to select boundary or non-boundary chips in this condition. It was only when the chip to be detected crossed into another category, and had a different colour name, that J.G. selected it. On this condition he performed at ceiling.

When discriminations were carried out on red/yellow chips, J.G.'s performed again at ceiling and he correctly identified all stimuli drawn from the red/yellow ranges. Controls had shown relatively poor discrimination performance with small and medium intervals, although performance of large intervals, where target chips were at category boundaries, was good. Yellow and red are colours that J.G. is particularly unable to tolerate, and it is interesting that he shows enhanced discrimination of these stimuli. He reports reduced visual stress symptoms when looking at blue and purple and it was interesting that his discrimination of stimuli normally labelled blue was relatively poor. One explanation for this is that blue causes the least discomfort and so J.G. does not process the stimuli as intently as the colours that cause him the most discomfort.

However, his naming of green, blue and purple Munsell chips revealed tighter category boundaries for the blue range and whereby wider category boundaries for green than either the TD or HFA groups. In the categorisation task (chapter four, experiment eight) when chips were drawn from the blue/purple range, J.G.'s discrimination of boundary chips was good and his performance, like that of his HFA counterparts, was better than that of controls. However, on the within-category condition, he did not select the chip nearest to the boundary whereas controls (HFA and TD) selected them on 80% of presentations. The extent that the theories of autism and of colour processing can accommodate these findings will now be discussed.

The EPF (Mottron & Burack, 2001) and RG (Plaisted, 2001) theories of autism both propose that autism is characterised by particularly good discrimination of perceptual stimuli. Whilst both theories allow that many of the abnormalities seen in autism are domain-general and higher-level, they nevertheless propose that the core abnormality is perceptual in nature. Thus, EPF reflects early over-activity in low-level perceptual modules that interfere with the development of higher-level domain general processes. According to the RG theory, enhanced performance on perceptual tests occurs because people with autism are particularly sensitive to unique features within stimuli, and less sensitive to features shared between stimuli. Whilst these explanations for enhanced performance on perceptual tasks are not dissimilar to Frith (1989) and Happé's (1999) concept of enhanced local processing, WCC theory differs from the EPF and RG theories in proposing a core deficit in global or holistic processing. Whilst global or holistic processing is currently not well defined in the WCC theory, it seems plausible to suggest, particularly in the light of studies showing how language impacts on the perceptual processing of colour (Kay & Kempton, 1984; Roberson, Davies, & Davidoff, 2000), that language might well be considered an important mechanisms by which coherence is accomplished. Taking the case of J.G., it is clear that whilst his language, relative to his non-verbal intelligence, is poor, he uses verbal labels to name colours and remember colours. Although he does show some evidence of enhanced perception in on-line processing, he nevertheless adopts a verbal coding strategy in colour memory experiments, and in fact this was the case for all of the HFA participants. He also showed a powerful effect of verbal labelling on condition three of the categorisation study, where different category chips would possess a different colour name.

The findings from the group studies in chapter five highlighted the use of a verbal label strategy in colour memory in autism, and this has implications for theories of colour perception which will be further discussed.

In summary the findings from the study of J.G. in this chapter, suggest that colour obsessions in autism maybe one result of atypical sensory processing that gives rise to unpleasant symptoms of visual stress. Other outcomes of colour obsessions include enhanced discrimination for normally avoided colours and a relative insensitivity to favoured colours. Category boundaries appear to be influenced by colour obsessions and individuals with these difficulties may rely heavily on colour names on memory. The findings from the study of J.G. will be further considered in the general discussion.

CHAPTER SEVEN

GENERAL DISCUSSION

The studies presented in this thesis represent the first systematic investigation of colour processing in individuals with autism. Given that idiosyncratic responses to colour have long been reported in the literature (White & White, 1987; Williams, 1999), and colour therapies are increasingly considered to have beneficial effects for these individuals (Howlin, 1996; Irlen, 1991; Williams, 1999) such studies are much needed. Several influential theoretical accounts of autism have proposed that an important characteristic of these individuals is that they possess enhanced perception but that higher-level or global processing is significantly compromised. This issue of whether information is driven by top-down or bottom-up processes in autism is particularly interesting when considered in the context of colour processing. This is because researchers working on categorical colour perception are currently evaluating the relative contributions of perception and language to such processes.

The primary aim of this thesis was to establish whether children with autism would show abnormal colour processing, and how any such results could be interpreted within the context of current theorising about the disorder. The findings from the studies will now be discussed.

In order for a diagnosis of autism spectrum disorder to be made, individuals must present deficits in the three domains of socialisation, communication and imagination before they attain the age of three years (DSM-IV, 1994). As previously mentioned, abnormal responses to sensory stimuli were omitted from DSM-III (1980) because of confusion over the interpretation of such symptoms (Ornitz, 1989), and also because of the poverty of systematic empirical research in this domain (Fillipek et al.,1999). However, since DSM 1V was published in 1994 there has been an increasing awareness that sensory processing difficulties may be an important symptom in the clinical picture, for at least some individuals with autism (see Dawson & Watling, 2000). The children with autism who participated in the studies presented in this thesis were not screened for sensory abnormalities, and parental information was only obtained for J.G. Theoretical accounts of atypical perceptual processing in autism (WCC, EPF & RG) assume homogeneity in samples, and for the purposes of the current research such data was not of primary interest. The studies that examined the use of colour overlays in autism clearly showed their use resulted in increases in processing speed without compromising accuracy in many, though not all, children with this diagnosis. This suggests that these children are more susceptible to the types of visual disturbance associated with Meares-Irlen syndrome (Irlen, 1991; Wilkins 2003; Williams, 1999) than would be expected, given current diagnostic criteria. The clinical and theoretical implications of the studies presented in this thesis will now be discussed.

Clinically, the results of the experiments using the colour overlays are very important. Chapters two and three provide clear evidence for the beneficial effects of these overlays for individuals with autism spectrum disorders. A larger proportion of children from the autism group than from the control group improved task performance when using colour overlays, and for these children such improvements tended to be larger than those of the few controls who also showed such improvements.

The results of the experiments also provided preliminary support for the reliability and consistency of these overlays. When children were retested eight months after their first overlay test, a similar proportion of children from the two groups benefited to the same extent as on the earlier testing session. There was also a very strong effect of overlay colour choice across the tasks. The observation that children were able to select overlays that were effective over repeated testing sessions offers some support for the cortical hyperexcitability hypothesis. According to this hypothesis, the remediation effects of overlays occur because they change the locus of activation from hyperexcitable areas to areas that are not hyperexcitable. As the location of these areas of hyperactivation differs between individuals, the process of selecting appropriate overlays can only be carried out by the individual concerned. The individual's cue for optimal overlay choice is his/her perception of reduced hyperactivation in response to the specific overlay/s selected.

The findings from the studies presented in chapters two and three highlighted some of the potential academic benefits that may accrue as a result of using these overlays. Whilst it is clear that autism-specific difficulties with academic tasks like reading cannot be solely attributed to visual perceptual difficulties, they may well be a contributory factor. Indeed increased reading speed, seen in children with autism in the current studies, suggests that this is the case. It is thus proposed that when considering the complex and diverse difficulties in information processing in autism, cortical hyperexcitability is included as a potentially contributory factor.

Further research into the cortical hyperexcitability theory may also be important in enabling researchers to link abnormalities in specific brain areas such as the cortical regions, with deficits in different aspects of cognition. Of all the groups tested with colour overlays to date, those with autism have been found to show the largest benefits. In the introduction to the thesis, a range of central nervous disorders including dyslexia, epilepsy, migraine, head injury and multiple sclerosis were proposed as candidate groups for colour overlay therapy. Indeed this proposition has gained some support from empirical studies (e.g. Wilkins, 2003). However, many of these studies have concentrated on ameliorating visual perceptual distortions, and no study has reported positive effects for such large proportions of individuals within groups, or such large percentage gains on academically related tasks as was seen in the studies described this thesis (Jackowski et al., 1996; Wilkins, 1995; Wilkins & Nimmo-Smith, 1987; Wilkins et al., 1999). Importantly, the findings from the overlay studies show that beneficial effects extend to autistic children with significant intellectual difficulties. In contrast, MLD children included in control groups did not show greater benefit than typically developing controls.

The study reported in chapter six provides an instructive example of cases where colour processing abnormalities are particularly profound. This chapter presented a case study of J.G., an eleven year old boy with Asperger syndrome, whose obsession with the colours blue and purple and a very limited tolerance to other colours was shown to have impacted on different aspects of his daily life in profound ways. Of particular relevance, when considering the results from the group overlay studies, was the finding that J.G.'s self-selected colour overlays corresponded to his colour obsession (blue and purple), and he showed large increases in performance speed on the various tasks he completed when using these specific overlays. Unlike the other HFA participants, J.G. was able to describe symptoms of visual stress when viewing the test stimuli without colour overlays. If, as the cortical hyperexcitability hypothesis suggests, self selected colour overlays reduce hyperexcitability by redistributing excitation in such a way that discomfort is avoided, it is plausible to suggest that J.G.'s colour obsession has increased the extent that he can function well in his everyday world. Thus, he is able to enjoy being in his room at home because it is painted purple and blue and does not have bright lighting. He can participate in family trips because the family car is blue and purple. It may be the case that other children with autism, with equally marked colour processing abnormalities as J.G., but possessing poorer communication skills or poorer support networks, would not have made such gains developmentally. The improvements in performance on the overlay experiments, seen in the children with autism, would not have been predicted from their verbal reports of stress symptoms. Given that many of the participants were relatively verbal, this is clearly an important problem. Sensory processing difficulties, prevalent in autism, tend to ameliorate with age (Dunn, 1999), although their early effects may have far reaching consequences developmentally. The development of appropriate screening methods and the establishment of early screening timetables should therefore be a primary aim for researchers working with children with autism.

It is important to note, when considering the case of J.G, that his sensory processing difficulties were not limited to the visual modality. Indeed he also reacted negatively to particular classes of auditory input. However, localised hyperexcitability may also occur in the auditory cortex and these difficulties can be accommodation by the cortical hyperexcitability hypothesis.

Just et al., (2004) propose the underconnectivity theory which suggests that there may be preservation and/or enhancement of the functions of individual cortical centres, and poorer integration of information at the higher levels required among the cortical centres. The notion of enhanced cortical centres is similar to that of enhanced perceptual functions, proposed by Mottron and Burack (2001). However, whilst these accounts offer a plausible explanation for why good performance on perceptual tasks has been seen in some experimental studies, they fail to account for potentially negative consequences arising from cortical hyperexcitability. This will be further discussed.

One very surprising finding that emerged from the studies was that many of the children with autism who showed large benefits from colour overlays did not appear to differ from autistic children or indeed from controls who showed no such benefits, on investigations into colour perception, categorisation and memory. Thus, whilst the findings from chapters two and three did suggest atypical visual processing in the majority of children with autism, these did not appear to impact on other aspects of colour perception to any significant degree. This was not the case for J.G., and his performance on the tasks into perception, categorisation and memory clearly linked back to his unusual pattern of colour processing. It may then be the case such children represent a distinct sub-group that might well be the focus for future studies.

In conclusion, the findings from chapters two and three showed that a large proportion of children with autism benefited from the use of colour overlays, and it was suggested that these findings could have significant implications for many aspects of their development, particularly within the academic environment. The colour of the overlay chosen appeared to be very specific, and consistency in colour choice was shown across tasks. The case study of J.G. highlighted the importance of overlay choice in reducing visual stress, and it was also suggested that when colour processing abnormalities are severe they may have a far-reaching impact on development in autism. Finally, early and appropriate screening for symptoms of visual stress was advocated.

A different approach to the investigation of colour processing was taken in chapters four and five. In chapter four, children were tested across different areas of colour cognition using various paradigms. In experiment five, the children were shown colour chips and asked to name each colour, and in the comprehension part of the experiment they were required to point to the relevant colour chip when its name was given. Colour discrimination ability was then tested in experiment six. Here, children were shown three patches of blue, green, red or yellow, and were asked to identify the one that was different to the other two. The distance between the different patch and the two other patches was manipulated in three conditions, in which hue distance was varied systematically. The perceptual distances for all three experimental conditions remained within category for the blue and green patches, although the in-the-large perceptual distance condition straddled or crossed category boundaries for yellow and red stimuli. Colour categorisation was explored in experiments seven and eight. Experiment seven attempted to determine category boundaries across the blue/green and blue/purple ranges. Here children were required to name manually presented Munsell chips. In experiment eight, the children were required to judge which of three chips was the most different. In this experiment triads of chips were (1) all within category; (2) included two within category and one boundary chip; or, (3) included two within category chips and one from another category. The findings of the first of this group of studies, comprehension and naming, showed that for the vast majority of children with autism, colour naming and comprehension were relatively unimpaired. Although a small sub-group of children with autism were unable to name colours, it seemed likely that this reflected more general speech production problems. Certainly the children in this sub-group, like the rest of the children in the autism group showed high levels of colour name comprehension. The findings from experiment six that manipulated perceptual distance in order to test perceptual discrimination ability showed that diagnosis was only an important factor when it co-occurred with significant intellectual impairment. Here, the performance of the HFA children was indistinguishable from that of the TD controls. Qualitatively their performance was also like that of the MLD controls, though their scores tended to be higher. Perception of differences between stimuli that were blue and green increased in line with increasing perceptual distance. However, this was not the case for red and green stimuli, and here discrimination performance was less influenced by perceptual distance than by the category boundaries.

The findings from the two categorisation studies showed an interesting pattern of performance that appeared to be related to both diagnosis and intellectual level. The first of these studies involved naming the colours of stimuli, and earlier findings had shown that this was difficult for some intellectually impaired children with autism. Consequently, only a small proportion of these participants were included in the study. The findings from this study appeared to show category boundary differences across the blue/green boundary between children with autism and their controls. However, the effect was not statistically significant. The second categorisation study did not involve naming and a larger sample of LFA children participated. The findings from this study supported the suggestion that that colour categories may be different in autism when compared to controls. However, the children with autism did not perform in a uniform way and it appeared from the data that cognitively unimpaired children with autism possessed rigid category boundaries, in comparison to TD controls, and cognitively impaired children with autism categorised colours more loosely than their age and intelligence matched controls.

An important aspect of these studies was to test the theories of autism and colour processing outlined in the introduction. The enhanced perceptual functioning (EPF) theory (Mottron & Burack, 2001) proposes that there is an over-development of low level perceptual features which override higher level processes in autism. Consequently the detection, discrimination and the categorisation of perceptual stimuli are assumed to be enhanced in autism. The findings from chapter four failed to provide support for the EPF theory as the performance of the HFA children was strikingly like that of TD controls, and the LFA participants showed poor discrimination performance. Plaisted's (2001) reduced generalisation (RG) theory predicts that the enhanced salience of unique stimulus features results in narrow category boundaries in autism. Whilst the findings from the experiments in chapter four provide limited support to this theory, in that narrower category boundaries were found in the HFA group relative to the TD controls, the LFA children showed looser category boundaries than their MLD matched controls. Furthermore, Plaisted's theory assumes that narrow category boundaries are a result of enhanced perception, and this did not appear to be characteristic of the participants in the current studies.

As outlined in the introduction, some researchers working in the area of colour processing have proposed that categorical perception is influenced by language (Kay & Kempton, 1984; Roberson, Davies & Davidoff, 2000). Such theorising has important implications when considering the case of the individual with autism, for whom language is both delayed and atypical. Recently, Franklin, Clifford, Williamson et al., (2005) have outlined a perceptual reorganisation theory, that takes into consideration the interaction between language and perceptual factors. This theory proposes that whilst perceptual categorisation is hardwired, category boundaries are reorganised at later stages in development (Franklin et al., 2005). Cultural factors, most importantly language, are then allowed to play a role in the formation of category boundaries.

The findings of spared colour naming and comprehension together with unexceptional perceptual processing in autism might lead to the conclusion that children with and without autism will show fewer dissimilarities within this domain than is usually the case. However, consideration of the matching procedures used in the studies presented in the thesis is important in this respect. The results from the studies suggest that the non-verbal matching criteria had worked well in that the children in the HFA and TD groups had shown similar levels and patterns of performance on the discrimination and naming task. Even though the mean BPVS (language) score for the HFA group was similar to the mean for the MLD group, their performance on the experimental tasks was very similar to that of TD participants and was also generally superior to that of the MLD group. The children in the MLD groups tended to show the same pattern of performance as those in the cognitively unimpaired groups (TD, HFA) although their overall scores were lower. It therefore appeared that whilst the HFA children were language impaired relative to the TD children, their non-verbal intelligence enabled them to overcome any difficulties associated with their delayed and atypical language skills. MLD children, like those with typical development, tend not to show large discrepancies between verbal and non-verbal intelligence, and in this respect differ from the children with LFA for whom verbal scores are frequently lower than non-verbal scores. It was noted that whilst the HFA and TD comparisons showed very similar task performance, a very different pattern was found when LFA and MLD groups were compared. The experiments presented in chapter five, attempted to determine whether children with autism would rely on language or perceptual information in memory, and clearly showed that the level of language skill was an important factor in determining memory strategy in autism.

In chapter five, experiments nine, ten and eleven tested the children on their ability to remember animals paired with either colours or colour names. The HFA, TD, and MLD children showed good memory performance in the experiments where a reliance on verbal labels would be expected to facilitate good performance (experiments nine and eleven). However the LFA children showed the opposite pattern, and performed significantly better on experiment ten where a tendency to encode perceptual information would be expected to convey an advantage. The analysis of the data showed that scores on experiment ten were found to be significantly and negatively correlated with verbal and non-verbal IQ. When an analysis was carried out on the data from the three studies together, it became clear that the participants with LFA relied on perceptual information in memory. However, the HFA children like their TD controls and the children with MLD relied on verbal labels in memory. This reliance on perceptual information in the LFA group is interesting when considered in the light of theories proposing enhanced perception in autism. The LFA participants did not appear to show enhanced perception in the earlier studies, and indeed they were poorer than HFA children in distinguishing differences between blue and green stimuli. However, they were nevertheless able to retain this information to a higher level than their more intelligent counterparts who appeared to rely more heavily on verbal labels. It was interesting that J.G. showed an absolute reliance on verbal labels in the group of memory studies, even though he did provide some evidence for enhanced perceptual processing in the earlier studies. Clearly theoretical accounts of atypical perception in autism require some reformulation. Most importantly, the assumption of homogeneity in autism samples should be questioned.

Indeed J.G.'s performance is better interpreted within the context of his colour obsessions. He obtained perfect colour naming and comprehension scores and also performed at ceiling on the perceptual distance task when the colour triads where not blue. When stimuli were blue his performance was at chance. His enhanced perception of colours that he finds aversive suggests that he is hypersensitive to their qualities. That he is even more likely to rely on a colour name encoding strategy than other children with HFA may reflect his reluctance to encode aversive perceptual information, when other strategy options are available. The findings from the two categorisation studies also suggest that he possesses a narrower category boundary for blue than HFA and TD controls. Clearly, further research into colour processing in individuals with strong colour preferences should be carried out.

Taken together, the findings from chapters four, five and six show that language as well as perceptual information is important in colour processing in autism. However, the findings also suggest that LFA children, who have poor language, rely on perceptual information in memory more and language information less than their more able counterparts. The Weak Central Coherence theory has attempted to account for atypical information processing in autism and assumes that higher order mechanisms such as language will exert less influence on lower-level perceptual and cognitive processes. This then has relevance for theories of colour that place emphasis on the organisational functions of language. The perceptual reorganisation theory (Franklin et al., 2005) accounts for both linguistic and perceptual factors in colour categorisation, and provides an account within which differences between HFA and LFA children can be considered. If language is important in the shaping of categories, it is unsurprising that children with autism, for whom language is delayed and atypical, show atypical categorical perception. It thus appears that an account based on the perceptual reorganisation and weak central coherence theories best explains the findings from the studies presented in chapters, four, five and six.

In her original formulation of the WCC theory, (Frith, 1989) suggested that people with autism cannot see the wood for the trees; in other words gist processing is compromised in autism. It seems likely that a week tendency to perceptually group stimuli will impact negatively on social, communicative functions. For example, perceptual categories for emotions on faces and in voices enable individuals to make rapid inferences about the people they interact with. Applying such reasoning to the colour domain it could be argued that the use of colour names enables groupings that are also highly functional. For example, an inability to know which objects are blue would be much more disadvantageous than an inability to distinguish and remember which particular shade of blue an object was. Because people with autism have compromised Gestalt processing, the importance of global category (i.e. blue) is weaker in relation to "local" elements such as particular shades of blue. If such a tendency is characteristic from infancy, it may well impact on the formation of categories. Categorical perception leads to perceptual distortion such that pairs of stimuli that cross category boundaries are perceived as more dissimilar that widely spaced pairs that are within categories. A tendency to WCC would be predicted to reduce the extent of perceptual distortion and result in equivalent salience for stimuli, independent of their relationship to category boundaries. However, in the current studies the performance of the HFA children suggested that for them category boundaries were tighter, and J.G. showed a similar but more marked effect. It also appeared from the findings that the children with autism and significant language impairment were relatively insensitive to category boundaries, and were also better able to remember individual colours (as demonstrated in experiment ten) than their higher functioning counterparts. Whilst they had been found to have acquired colour names it may still be the case that their unusual pattern of performance relates to their poor and late developing language skills.

Whilst many high functioning individuals with autism develop language skills, research has shown that these skills are very uneven (Lord et al., 1997; Minshew, Goldstein & Siegel, 1995; Rapin, 1996; Tager-Flusberg, 2001; 2003). One unusual aspect of the language of individuals with autism is its concrete, inflexible nature. For example, after J.G., the child described in chapter six was told that the family computer had a virus, he responded by taping the cracks around the doors and windows. Whilst the isolation of a virus would be extremely important in some contexts it was not the case in this context. Such confusions form an everyday occurrence in the lives of able people with autism. Perhaps then, J.G.'s concept of blue is infinitely less flexible than would normally be the case. Certainly, he did not seem very sensitive to differences within this colour category, and it appeared that his category boundary for this colour was tighter than that of controls. The other able autistic participants, who would also have shown a tendency towards literal interpretations, also provided some evidence for narrower category boundaries.

Thus, the qualitative difference in category boundary processing may well reflect a more general tendency towards rigidity in verbal labelling in able people with autism. For individuals whose language development is more severe, top-down effects of language on perception may be weak. Certainly the findings from the various studies show that their pattern of performance on tests of colour processing clearly distinguish them from other, more able individuals with autism, and from age and non-verbal intelligence matched controls.

In conclusion, theoretical accounts that place emphasis on top down processes are better able to account for the studies presented in this thesis than accounts that stress bottom up processes. Further, theoretical accounts of autism should allow for the importance of language as well as the types of perceptual disturbance that results from brain abnormalities. Whilst the WCC theory provides an important framework for understanding autism, it is not able to account for individual differences well. The case of J.G., who showed marked differences in performance across the colour discrimination and categorisation tasks compared to both autism and control groups, illustrates the importance of individual case studies. Neurological theories like the one proposed by Just et al., (2004) are likely to be an important influence on future research, although current practices of averaging data across small numbers of participants are particularly problematic in explaining groups where variation across a wide range of variables is likely to be particularly large.

The studies that have been presented in the thesis are the first to directly investigate colour processing in autism spectrum disorders. The findings from the studies have revealed a complex pattern, encompassing both typical and atypical performance across different aspects of colour information processing. In interpreting these findings, it was concluded that perceptual processes, language and experiential factors are likely to have contributed to the observed findings, and weaknesses in current theoretical accounts of autism were outlined. Of significant educational importance were studies showing how colour overlays enable some children with autism to process visual information more efficiently. Future research might extend the current findings in several ways. For example, the early identification of children like J.G. who have extreme aversive reactions to particular colours, might impact positively on these children's development, particularly if early intervention can be achieved. Therefore effective screening methods should be developed. The use of colour overlays in neurological studies might enable researchers to refine theories of cortical hyperexcitability in autism. Larger scale overlay studies might also collect language data, diagnostic data and sensory profile data in order to determine whether there are sub-groups within the spectrum that respond particularly well to therapeutic interventions using colour. The question of colour perception and categorisation and the role of language in these processes clearly merits further study. Finally, group studies of children like J.G., who show extreme idiosyncratic responses to colour may enable researchers to further refine theories of autism, as well as theories of perception and categorisation.

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APPENDICES - MISCELLANEOUS WORKING PAPERS

APPENDIX (I) - Sheet 1 of 1

The Colour of the Overlays Chosen by the Children with Autism and their Controls in Chapter Two (Chapter two-experiment one)

Colour overlay	Autism group	Control Group
No overlay	0	3
Rose	0	1
Purple	2	0
Mint	4	3
Lime	1	0
Blue	0	3
Aqua	1	2
Yellow+Yellow	0	2
Yellow+Orange	1	0
Orange+Orange	1	1
Pink+Purple	1	1
Pink+Rose	1	0
Lime+Mint	2	1
Mint+Mint	2	0
Mint+Aqua	2	2
Blue+Aqua	1	0

APPENDIX (II) - SHEET 1 of 1

RATE OF READING TASK (CHAPTERS TWO AND THREE EXPERIMENTS ONE AND TWO)

come see the play look up is cat not my and dog for you to
the cat up dog and is play come you see for not to look my
you for the and not see my play come is look dog cat to up
dog to you and play cat up is my not come for the look see
play come see cat not look dog is my up the for to and you
to not cat for look is my and up come play you see the dog
my play see to for you is the look up cat not dog come and
look to for my come play the dog see you not cat up and is
up come look for the not dog cat you to see is and my play
is you dog for not cat my look come and up to play see the
see the look dog and not is you come up to my for cat play
not up play my is dog you come look for see and to the cat
look up come and is my cat not dog you see for to play the
my you is look the dog play see not come and to cat for up
for the to and you cat is look up my not dog play see come
you look see and play to the is cat not come for my up dog
come not to play look the and dog see is cat up you for my
and is for dog come see the cat up look you play my not to
dog you cat to and play for not come up the see look my is
the come to up cat my see dog you not look is play and for

Make two photocopies of the page and place side by side.

VISUAL STRESS SYMPTOMS (CHAPTERS TWO AND THREE)

Intuitive Overlays Record Sheet

Name : .... Date : ....

Date of Birth : .... Male/female

Class : .... Examiner's initials...............

Symptom Questionnaire

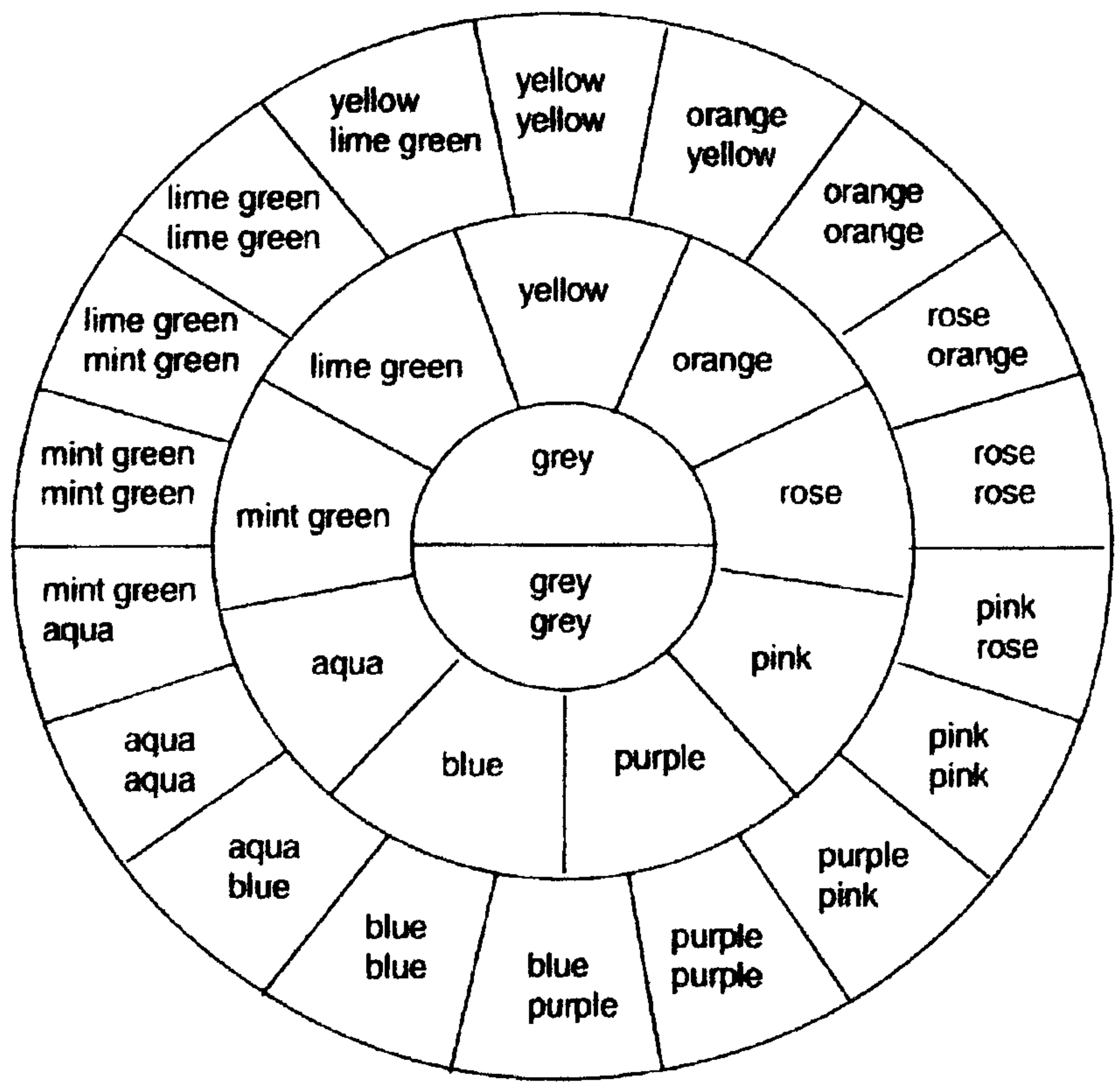
Ask question when individual is looking at text on Test Page.
*Response that is **underlined** scores 1; others score 0.*
Enter score in box.

	White page	Single overlay	Double overlay
"Do the letters stay still or do they **move**?"			
"Are the letters clear or are they **blurred**?"			
"Are the words **too close together** or far enough apart?"			
"Is the page **too bright**, not bright enough, or just about right?"			
"Does the page **hurt** your eyes to look at, or is it OK?"			

There is no hard and fast rule relating the above symptoms to benefit from overlays, although, in general, the greater the number of symptoms reported, the greater their reduction with the optimal colour, the more likely it is that the overlay(s) will be used, and the greater the increase in reading speed that results. See Wilkins, A.J. Lewis, E., Smith, F. Rowland, E., Tweedie, W. (2001). Coloured overlays and their benefit for reading. *Journal of Research in Reading*, **24**, 41-64.

Colour of single overlay .... Colour of double overlay (if needed)...........................

You can use this diagram to keep track of the overlays and combinations of overlays you have tested. The colours formed by the single overlays are shown in the inner ring. The colours given in the outer ring are formed by placing one overlay on top of another. Grey overlays are only rarely of benefit.



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APPENDIX (IV) - SHEET 1 of 5

COMPREHENSION TASK – SCOLP (Baddeley et al., 1992)

(CHAPTER THREE - EXPERIMENT FOUR)

Example

Are they true sentences?

Examiner

Fish live under the water	
People have two noses	

Practice.

Child

Bicycles have wheels	
We see with our ears	
Flowers wear clothes	
Milk comes from cows	

APPENDIX (IV) - SHEET 2 OF 5

Name................ Date.....................DOB.............
With/without overlay Test number 1 2 3 4 5

A side 1

We drink when we are thirsty	
Potatoes can be eaten	
We use the moon to stir things	
Oranges are fruit	
The sun is hot	
Tears come out of our eyes when we cry	
Oranges fall from the clouds	
Fathers have wings for flying	
Cats wear shoes	
Wood comes from the clouds	
Houses have six legs	
We eat shoes	
We stand on our elbows	
Dogs grow out of the ground	
Cats are living creatures	
The moon shines underground	
Fruits grow on trees	
Birds can live in trees	
Trees grow out of the ground	
Smoke comes from fire	

Duration..

APPENDIX (IV) - SHEET 3 OF 5

A side 2

The moon has two feet	
Dogs bark	
Trucks have wheels	
Houses wear clothes	
Dogs have wheels	
The sky gets hot at night	
Fathers are men	
Wood comes from trees	
Clothes have roots in the ground	
We use heat to cook food	
Trucks grow on trees	
Fathers have four legs	
Your teeth are in your mouth	
Doctors are people	
The sky has two ears and four legs	
Leaves grow on trees	
Puddles are wet	
Tables can walk	
Rabbits can sing	
We see with our eyes	

Duration...

Name................ Date....................DOB.............
With/without overlay Test number 1 2 3 4 5

B side 1

Dogs can run	
Birds have wings	
Tables have teeth	
Your feet are at the end of your legs	
Noses shine at night	
Spoons have sharp teeth	
Stones are hard	
We see things with our noses	
Birds can sing	
Stones grow on trees	
Your toes are attached to your hands	
When people get old their hair can go grey	
Birds wear shoes	
Fish can sing	
Soldiers have teeth	
When stones get old they get grey hair	
Lions use sharp knives to cut things	
Fish can swim	
Chairs are for sitting on	
Dogs have two ears on their heads	

Duration ....

APPENDIX (IV) - SHEET 5 OF 5

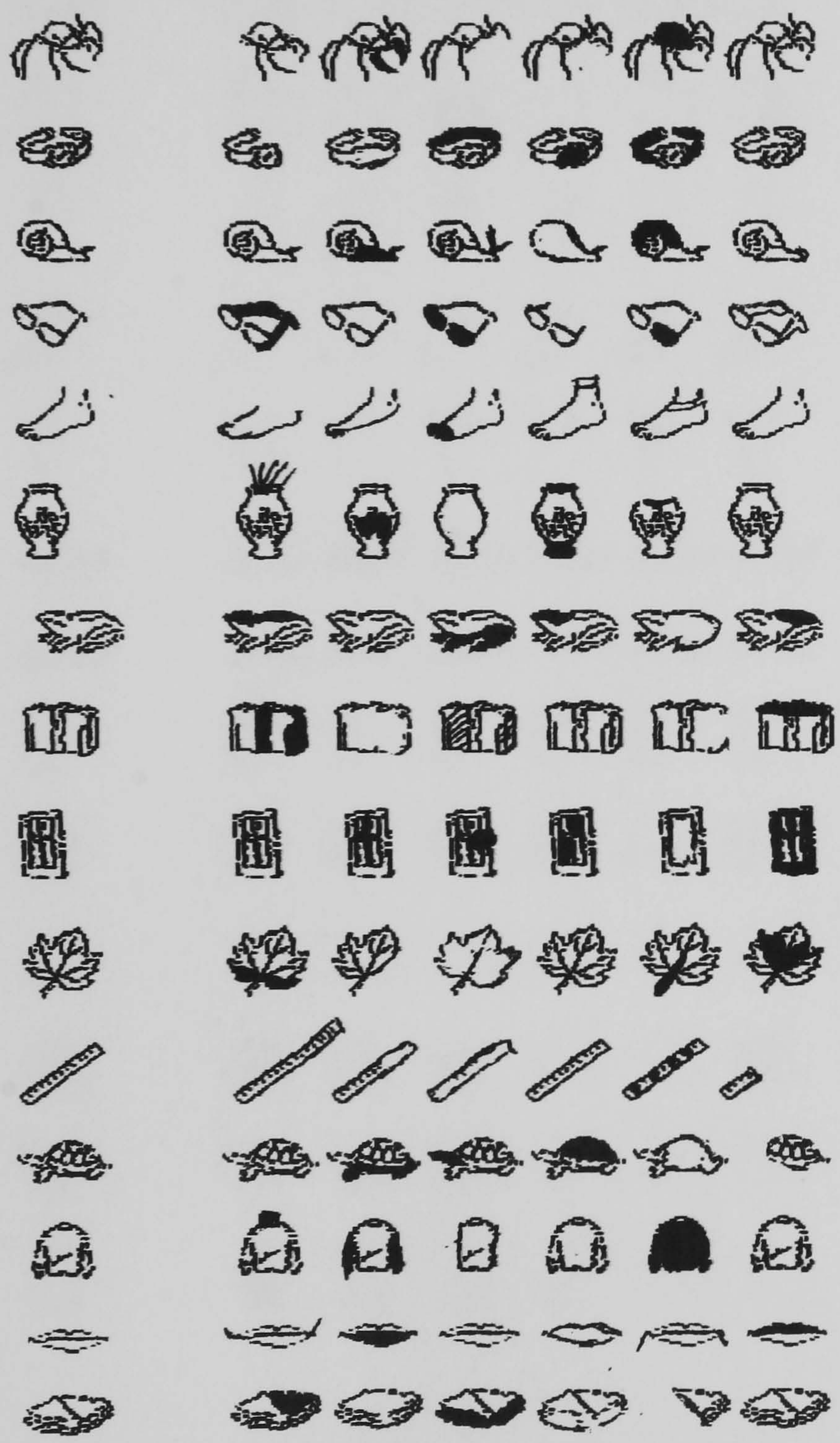
B side 2

Shoes are worn on feet	
Lions have fins for swimming	
Apples have wings	
Buses have eyes	
Lions have long tails	
Noses can smell smoke	
We use sharp knives to cut things	
Yours eyes are behind your knee	
Knives have legs	
Birds have whiskers	
Dogs have four legs	
Onions have legs	
Your nose is in the middle of your face	
Chairs have ears	
Owls have wings	
Cats have small noses and whiskers	
Cows eat grass	
Rocks can run	
Cars are made from cheese	
Birds eat worms	

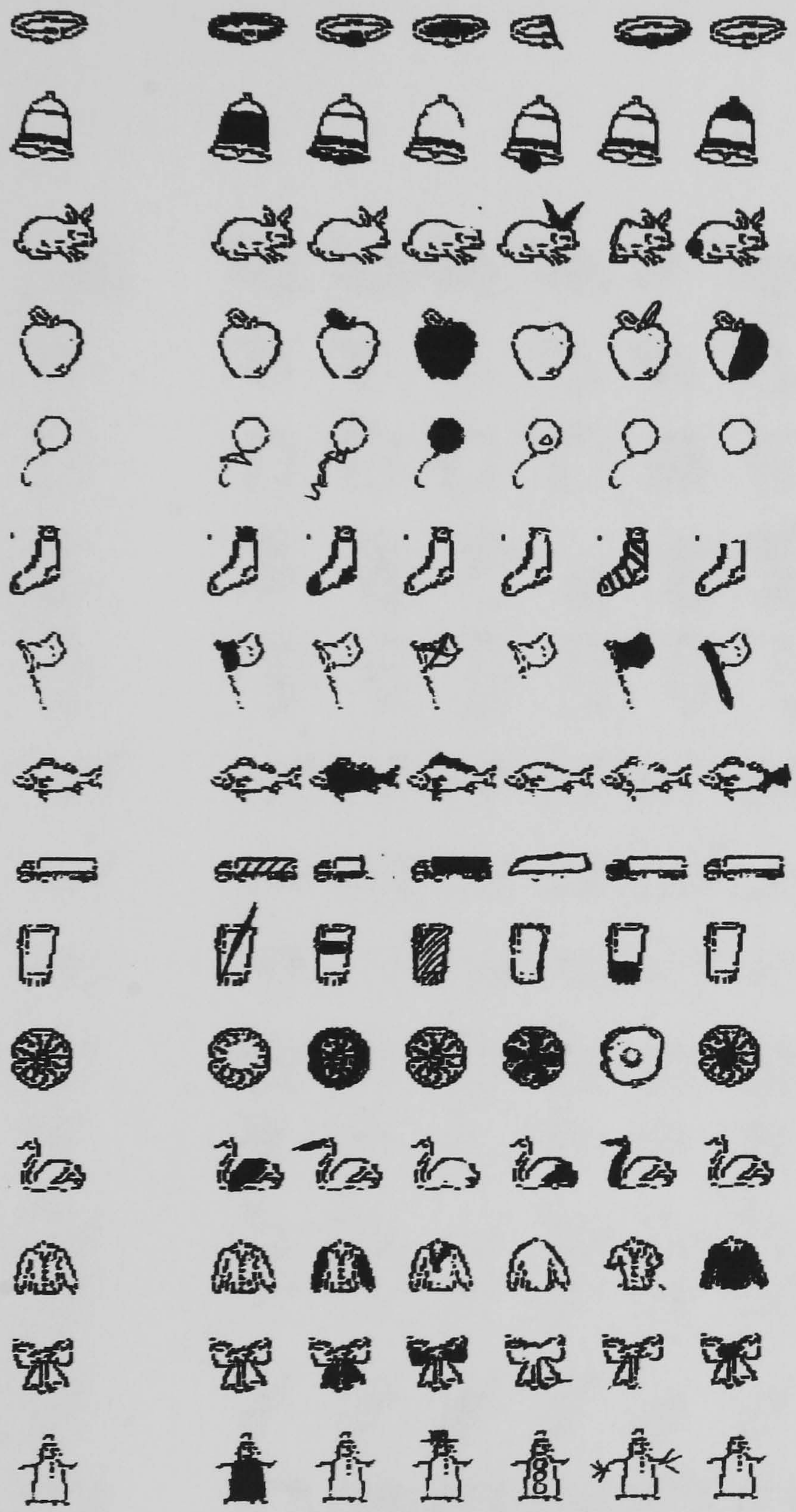
Duration ....

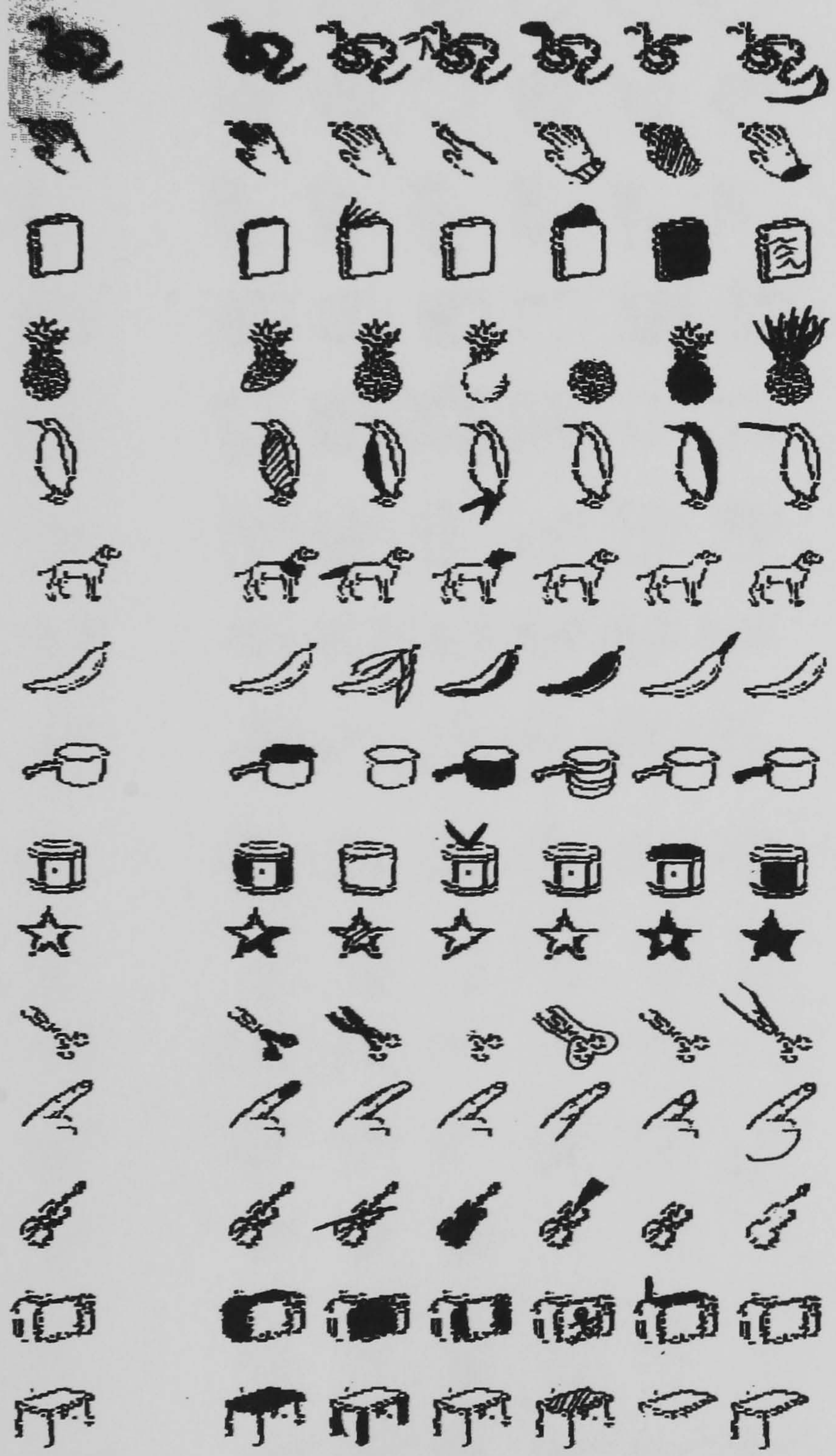
APPENDIX (V) - SHEET 1 OF 4

CHANGE DETECTION TASK (CHAPTER THREE EXPERIMENT FOUR)

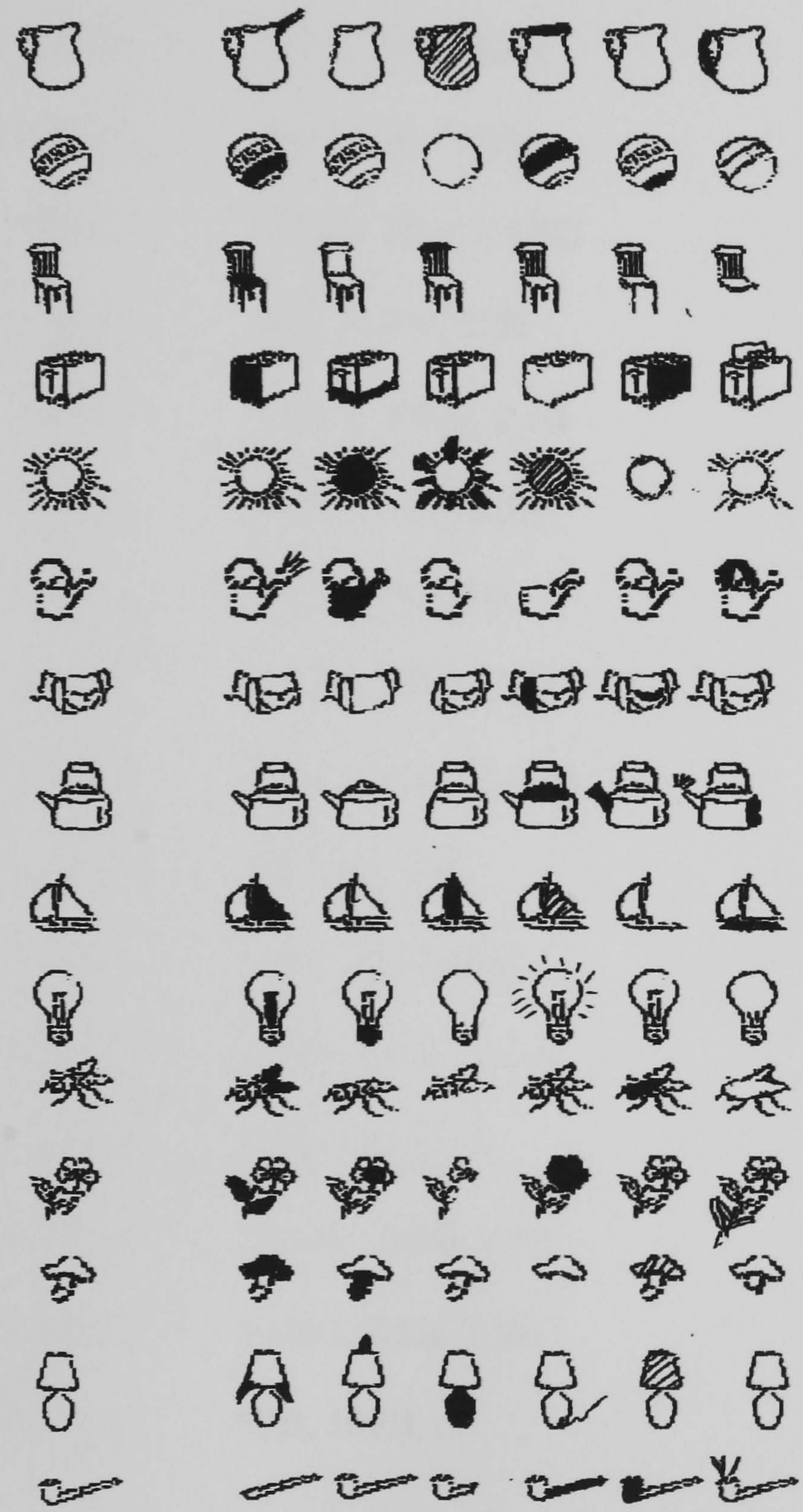


APPENDIX (V) - SHEET 2 OF 4





APPENDIX (V) - SHEET 4 OF 4



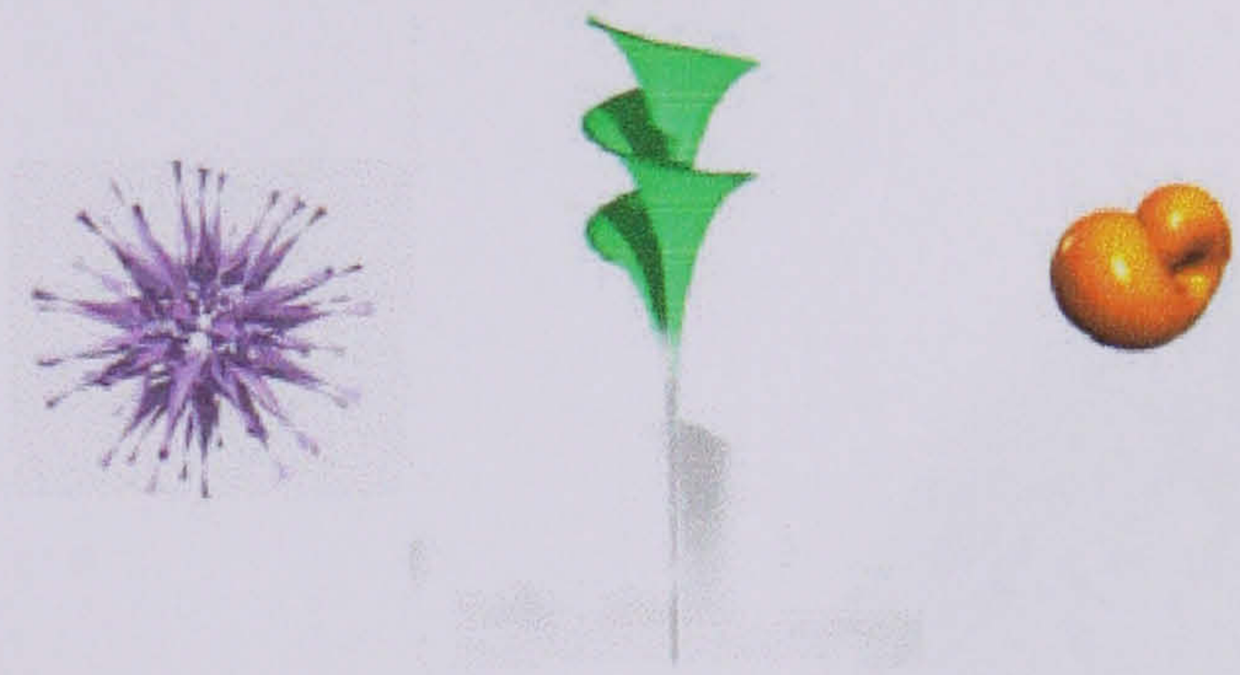
APPENDIX (VI) - SHEET 1 OF 1

CATEGORISATION – TRIAD STIMULI

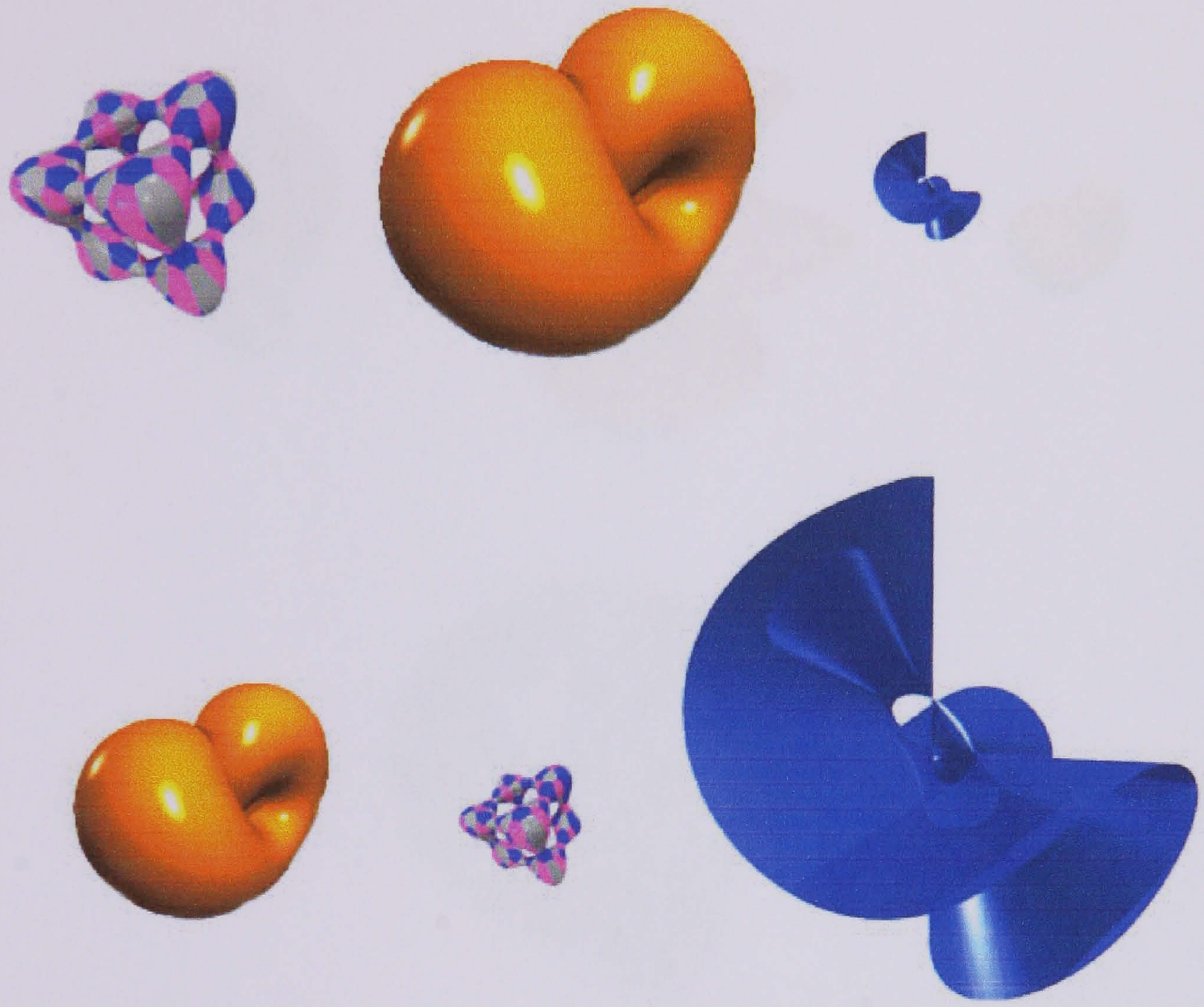
Triad 1-	10G, 2.5BG, 5BG
Triad 2-	7.5B, 10B, 2.5PB
Triad 3-	2.5BG, 5BG, 7.5BG
Triad-4-	10B, 2.5PB, 5PB
Triad-5-	7.5BG, 10BG, 2.5B
Triad-6-	5PB, 7.5PB, 10PB
Triad-7-	10BG, 2.5B, 5B
Triad-8-	7.5PB, 10PB, 2.5P
Triad-9-	7.5G, 2.5BG, 7.5BG
Triad-10-	5B, 10B, 5PB
Triad-11-	10G, 5BG, 10BG
Triad-12-	7.5B, 2.5PB, 7.5PB
Traid-13-	5BG, 10BG, 5B
Triad-14-	2.5PB, 7.5PB, 2.5P
Triad-15-	7.5BG, 2.5B, 7.5B
Triad-16-	5PB, 10PB, 5P

APPENDIX (VII) - SHEET 1 OF 8

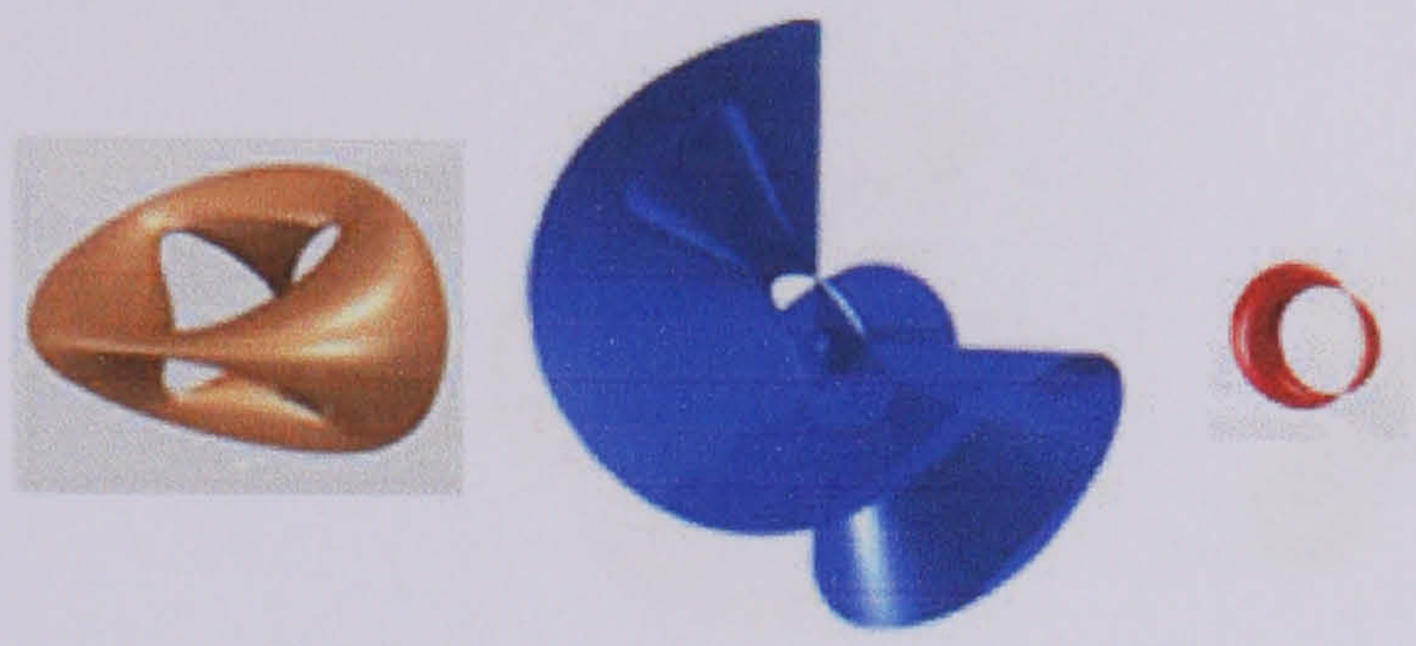
CATEGORISATION PRACTICE STIMULI (CHAPTER FOUR EXPERIMENT EIGHT)



APPENDIX (VII) - SHEET 2 OF 8

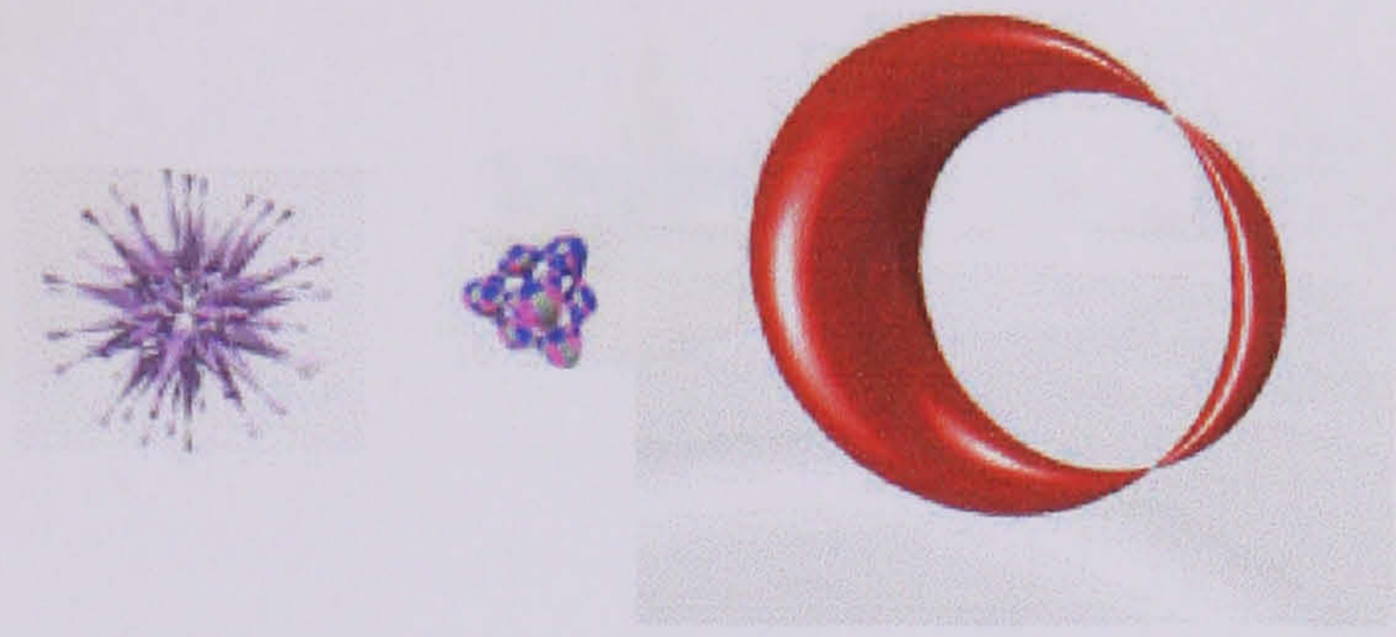


APPENDIX (VII) - SHEET 4 OF 8

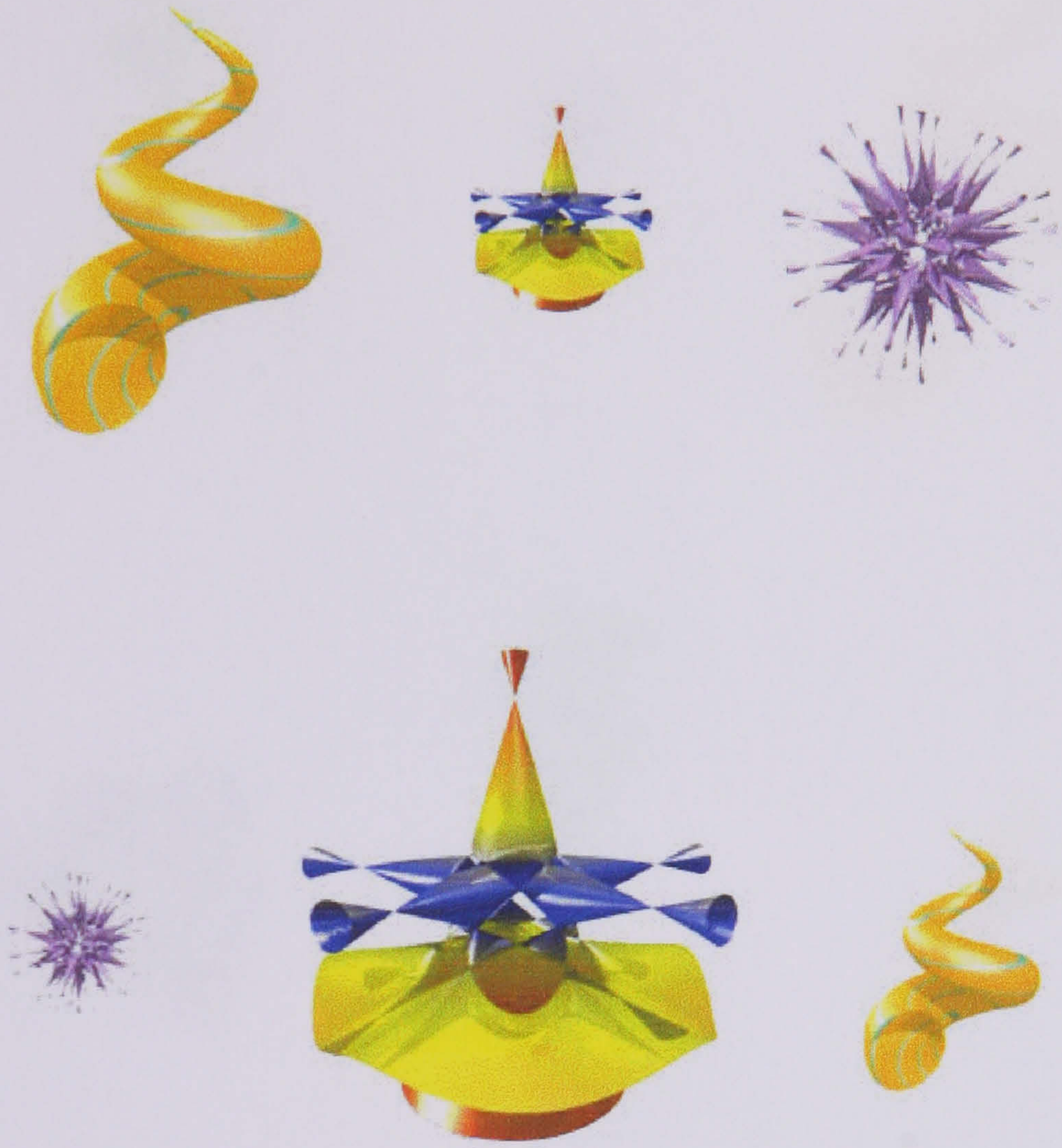


APPENDIX (VII) - SHEET 5 OF 8

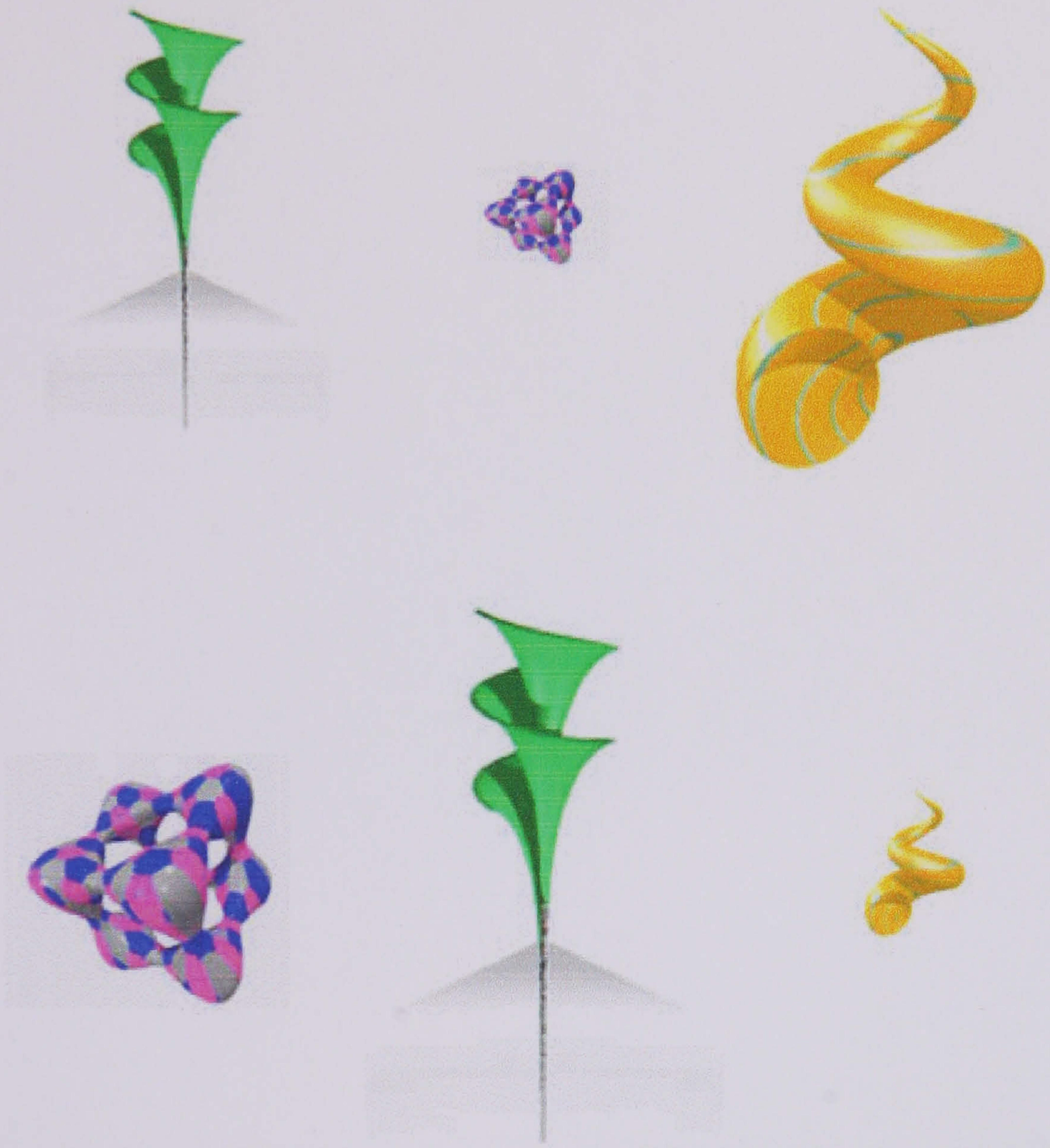
APPENDIX (VII) - SHEET 6 OF 8

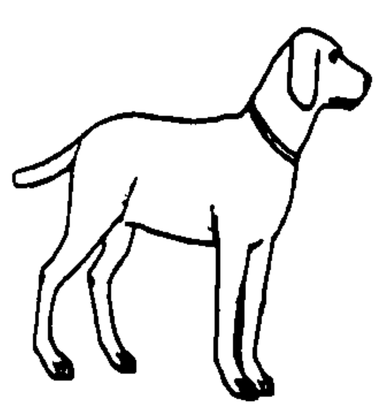
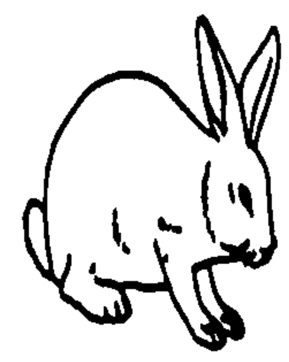
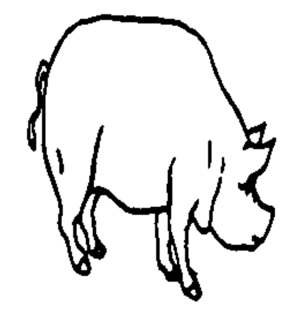


APPENDIX (VII) - SHEET 7 OF 8



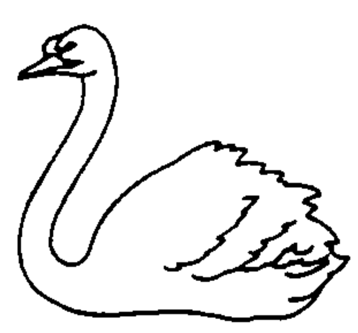
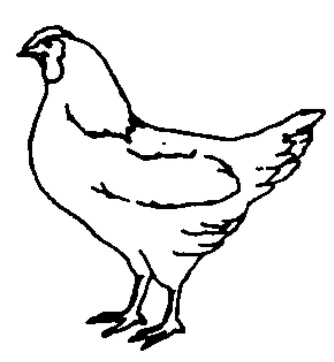
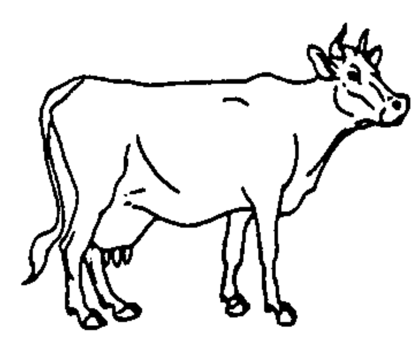
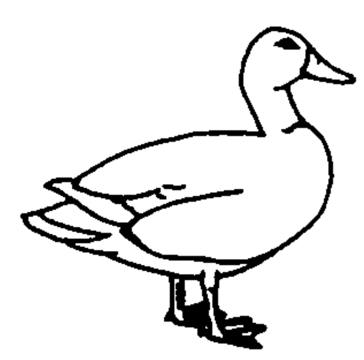
APPENDIX (VII) - SHEET 8 OF 8



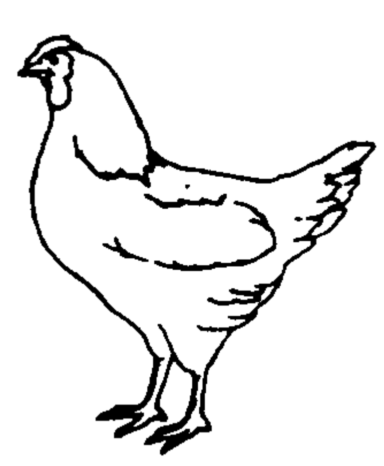
Familiarised with 5R	Familiarised with 5B	Familiarised with 5Y	Familiarised with 5G
Tested with 5R+5Y+5G+5B	Tested with 5B+5R+5G+5Y	Tested with 5Y+5R+5G+5B	Tested with 5G+5B+5R+5Y
Tested with 5R+1R+ 9R	Tested with 5B+1B+ 9B	Tested with 5Y+1Y+ 9Y	Tested with 1G+9G+ 5G

Experiment eleven

Familiarised with RED	Familiarised with GREEN	Familiarised with BLUE	Familiarised with YELLOW

Testing



- Yellow
- Green
- Red
- Blue