Perceptual Processing in Individual's with Autism

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Declaration

I declare that this thesis has not been presented, in this form or any different form, to this or any university in support of an application for any degree.

Signed,

Danielle Ropar

Abstract

The aim of this thesis was to explore perceptual processing in individuals with autism and Asperger's syndrome, and to assess the extent to which the theory of weak central coherence could account for any abnormalities in this area.

In Experiment 3:1 we presented individuals with autism with four illusions on a computer and asked them to adjust certain parts to appear the same. The results showed just as susceptible to illusions as those without autism on a computer task contrary to previous literature (Happe,1996). In Experiment 3:2 we presented the same illusions on card and asked participants to judge whether parts of the stimuli were the same or different as in Happe's procedure. Our results showed that autistic populations succumbed to illusions regardless of whether they verbally judged or manually made adjustments to the stimuli. This ruled out the possibility that procedural differences could account for our failure to replicate Happe's findings. These results show that coherence is intact at low levels of perceptual processing in autism.

Our second study (Experiment 4:1) explored whether individual differences in coherence may be able to explain why the results of Experiments 3:1 and 3:2 were not consistent with Happe's findings. We presented a battery of visuo-spatial tasks (block design, embedded figures, Rey complex figure test) and the visual illusion computer task to participants. Performance on these tasks was unable to predict susceptibility to visual illusions, suggesting that perception of illusions may not be related to weak central coherence.

Our final investigation explored whether autistic populations were more inclined to rely on visual rather than semantic properties when asked to pair atypically coloured pictures (e.g. blue banana) with colour patches (e.g. yellow or blue). Those with autism relied on background knowledge like control participants choosing the semantically related colour. We then considered whether requiring the participants to name the object before selecting a colour may have influenced

them to choose the semantic alternative in Experiment 5:2. Those with autism performed similarly to comparison groups choosing the semantic rather than the visual option. This demonstrated that background knowledge was just as salient to those with autism and Asperger's syndrome as those without autism.

There was little evidence from our investigations to suggest a deficit in coherence ability at the perceptual and verbal-semantic levels of processing. The theory of weak central coherence may need to be refined in order to account for our failure to find deficits in coherence in these areas. Other theories that may offer a more suitable explanation for our pattern of results are discussed.

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CHAPTER ONE

Review of the literature: Background on autism

1:1 Early accounts of autism

As with the present time, early accounts of autism defined the syndrome at the behavioural level. The first published accounts have been accredited to Leo Kanner (1943) of the USA and Hans Asperger of Austria (1944). Although these reports were written independently, they are very similar in their descriptions. In Kanner's paper he mentions many features which are still associated with autism today. The two main features described by Kanner are autistic aloneness and obsessive desire for sameness. By 'autistic aloneness' he meant a lack of social responsiveness and difficulties relating to people. This was not just a problem of shyness, but a serious impairment in the ability to experience affective contact with others. The second primary feature he describes is desire for sameness. Evidence of this was observed on occasions where autistic children were extremely upset by any changes in routine or aspects of their environment. In addition to these Kanner mentions other features he considers secondary such as repetitive behaviour and speech, lack of spontaneous activity, and oversensitivity to stimuli.

Kanner also acknowledges that despite these impairments autistic children may have 'islets of ability' which are preserved areas of functioning. For example, autistic children were found to have exceptional rote memory skills. Hans Asperger had noted many of these characteristics in the children he had observed. Asperger not only used the term 'autistic' to describe the children as Kanner had, but also mentioned the same constellation of features. In regards to the nature of autism, both Kanner and Asperger agreed that the disorder was innate and that it lasted throughout life into adulthood.

Despite the striking similarities between these two accounts, they were not in total agreement. The population that Asperger identified differed from Kanner's patients in some very distinctive ways. They were not only more fluent in verbal ability, but seemed better at spontaneous and abstract thought. However, in the area of motor ability Asperger reported clumsiness and poor co-ordination much more among his sample of children. The mismatch between Kanner and Asperger's accounts does not necessarily mean that they were describing different types of children. It has generally been accepted that Asperger was describing a subgroup on the autistic spectrum which today is referred to as Asperger's Syndrome. I shall discuss this in more detail in the following section.

1:2 Biological roots of autism

Currently there is increasing evidence supporting a biological rather than an environmental explanation of autism. The prevalence of autism seems to be one or two per 1000 births. Of those with autism there is a significantly greater number of boys than girls. Ratios for lower functioning individuals with autism are said to be 2 boys for every 1 girl (Ciadella & Mamelle, 1989), while the ratio of boys to girls is 5:1 in those at the more able end of the autistic spectrum (Lord & Schopler, 1987).

Findings in genetic research carried out with twins and siblings provides evidence that susceptibility to autism can be inherited. A review by Piven and Folstein (1994) explains that the likelihood of another sibling or fraternal twin having autism is slightly less than 3 per cent. Although this seems low, the occurrence of autism is 50-100 times greater than if the children were not related. Studies on identical twins showed a rate of concordance between 30 and 80 per cent. The large variance is likely due to the small sample size and considerable difficulty finding identical twins who are autistic. This evidence allows us to conclude that there can be a strong genetic component in autism. However, since there is not 100 per cent concordance of autism in identical twins environmental factors must also play a role.

Recently attention has focused on those aspects of autism that characterise the relatives of an individual with the syndrome. Piven and Folstein (1994) found that 30 per cent of parents having children with autism showed some autistic mannerisms themselves. Some of the characteristics the parents showed included difficulties with turn taking in conversation and problems understanding others' utterances or implied meanings. Further to this Baron-Cohen and Hammer (1997a) found that fathers of autistic children do very well on the embedded figures test. Exceptional performance by those with autism on this test has been taken as evidence of an 'islet of ability' that is associated with the syndrome. Another study (Happe, Briskman, & Frith, unpublished data) found further evidence to support an extended phenotype in autism. The fathers in this study performed similarly to their autistic children on various tasks such as superiority on the embedded figures test and block design test, and less susceptibility to illusions. There does seem to be some evidence that characteristics of autism (both assets and deficits) exist in parents of autistic individuals.

Although the evidence here suggests a more direct causal relationship between genes and autism, the syndrome may develop through an indirect route. There is evidence that children with phenylketonuria (PKU) are at risk of developing autism. PKU is caused by defective genes that stop the intestine from producing an enzyme that is essential for breaking down a certain amino acid (phenylalanine) in the diet. If caught at an early stage it is possible to alleviate the problem with a phenylalanine free diet; if it is undetected it may cause brain damage. The outcome of this damage may lead to autistic like behaviour in the child. In this way autism has a genetic basis that is mediated by an environmental factor such as diet.

1:3 Diagnostic Criteria Today

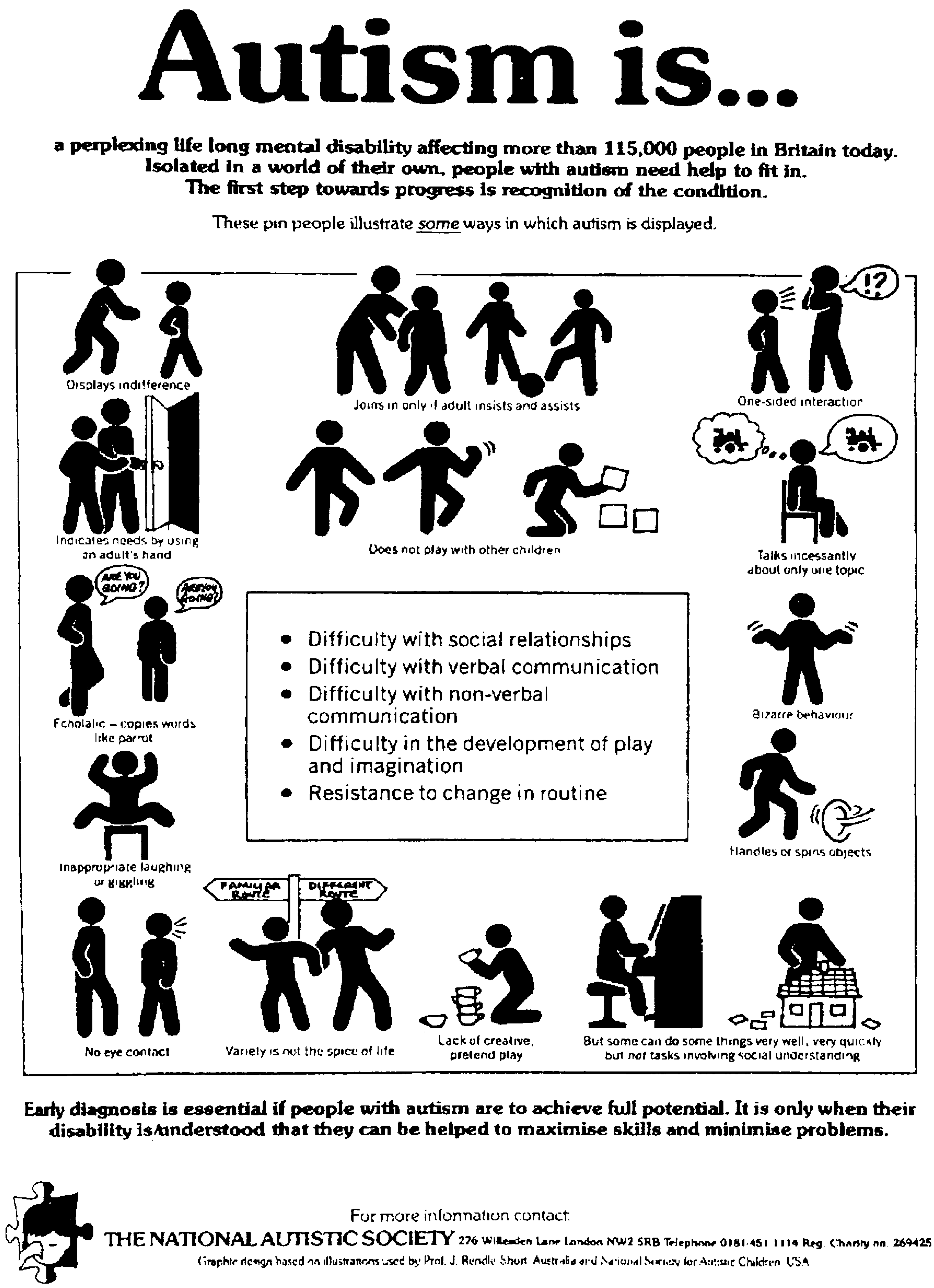
Many of the features described by Kanner and Asperger are included amongst the diagnostic criteria used to identify autism at the present time. In these earlier accounts, features such as perceptual abnormalities or special skills were just as important as deficits in language and communication in diagnosing autism. Today diagnostic tests have become increasingly more focused on social impairments as the criteria for classification. This shift in focus can be largely attributed to Wing and Gould (1979) who carried out an important epidemiological study to find the core impairments in autism. Problems of defining subgroups, and also with distinguishing autism from other related childhood conditions called for a reassessment of the classification system.

Wing and Gould (1979) attempted to address these problems by carrying out a survey of children showing evidence of language impairments, socialisation problems, or stereotypical behaviour. Their aims were to find the prevalence as well as the co-occurrence of these features. They also wanted to use their findings to help identify subgroups and clarify the relationship of these three abnormalities with mental disability. This study lead Wing and Gould (1979) to conclude that autism could be best described as a constellation of impairments in the areas of socialisation, communication, and imagination. The grouping of these features together has become known as Wing's triad. This study has had a significant impact on current psychological theories of autism which now tend to focus on explaining this triad of impairments.

Checklists such as the Diagnostic and Statistical Manual of the American Psychiatric Association (DSM IIIR, 1987 or DSM IV, 1994) and the International Classification of Diseases (ICD-10: World Health Organisation, 1993) also reflect the importance of these core features. Such checklists have assisted many psychiatrists in diagnosing individuals with autism. These diagnostic tools are widely used and provide practitioners with a list of behavioural characteristics specific to the syndrome or disorder. Many of the items focus on the atypical language development found in autism like echolalia and pronoun reversal. Other items such as "pervasive lack of responsiveness to other people" reflect social impairments or "autistic aloneness". Resistance to change is included under the statement "Bizarre responses to various aspects of the environment". The National Autistic Society has constructed a poster which illustrates some of these behavioural characteristics (see Figure 1:1). In order to avoid any confusion with other disorders like schizophrenia, the criteria require "an absence of delusions, hallucinations, loosening of associations and incoherence". These checklists are frequently revised as new findings in research are continuously changing the way we think about autism. More recently attention has turned towards identifying subgroups within the autistic spectrum.

Figure 1:1

National Autistic Society Poster



1:4 Subgroups of autism

Earlier I mentioned that the children Kanner and Asperger described may actually have been from different subgroups. Specifically, the children described by Asperger were more able than those Kanner observed. In 1981 Lorna Wing first used the term "Asperger's syndrome" to distinguish between those who did not fit Kanner's description of a socially withdrawn individual with minimal language skills. Although Asperger's syndrome has been suspected to be a subgroup of autism for some time, official diagnostic criteria for the syndrome have only been established in the last decade (World Health Organisation, 1990; DSM-IV, 1994). Both autism and Asperger's syndrome are classified as Pervasive Developmental Disorders and therefore have many features in common. These include impairments in social interaction, communication, and restricted range of interests. The main difference between Asperger's syndrome and autism seems to lie in the degree of impairment. For example, DSM-IV specifies that an individual with Asperger's syndrome should not possess a "clinically significant general delay" in language. Thus they should be competent in speaking single words by age 2 and simple communicative phrases by age 3. It is important to note that these individuals are still likely to experience difficulties understanding language when context is important (e.g. irony, jokes). A further specification is that they should not have a "clinically significant" cognitive delay. It is possible that some individuals with Asperger's syndrome may have learning difficulties, however most have average or above average intelligence. Another condition specified in DSM-IV is that the person does not meet criteria for another pervasive developmental disorder or schizophrenia.

Although guidelines have been set out for a diagnosis of Asperger's syndrome, it is still controversial as to whether it is a separate and distinct disorder from autism. Arguably, Asperger's syndrome is simply another term to describe individuals with higher-functioning autism. Indeed, the line between these two afflictions is thin, and clinicians may disagree about a diagnosis. Also, there are instances of a person being diagnosed with autism at a younger age, but fitting a diagnosis of Asperger's syndrome at an older age. This issue may raise several problems and has implications for the social services and treatment an individual will receive. For instance, some services may not provide the appropriate assistance if a person does not have the correct label. Also, the educational needs or treatment of an individual may vary depending on their diagnosis. By conducting further research comparing individuals with autism and Asperger's syndrome we may hope to gain a better understanding as to the exact relationship between these two disorders.

1:5 Historical Background

There is evidence that the syndrome of autism existed long before the term was first introduced. Initially individuals with autism were thought to be suffering from 'childhood schizophrenia' or were referred to as 'idiots'. They may have been abandoned or put in mental institutions because of their unexplainable, odd behaviour. Today autism is acknowledged as a pervasive developmental disorder that is clearly distinguishable from schizophrenia. Individuals with schizophrenia may suffer from delusions, unlike people with autism. Also, schizophrenia emerges in adolescence while evidence of autism can be found as early as two.

Given what we currently know about autism, it is possible to look back through history to find evidence of its existence before we had identified the syndrome as 'autism'. Some support for this dates as far back as the eighteenth century in accounts of feral children who grew up on their own in the wild. Uta Frith (1989) discusses the similarities between these cases and autism. One story describes an adolescent boy named Victor who was found in a forest in France. The boy, who has become known as the wild boy of Aveyron, was devoid of any language or social skills. He was taken under the care of Itard, who set out to try and educate the child. In Itard's work with Victor he mentions many autistic-like characteristics such as sensory abnormalities, stereotypical behaviour, and impairments in intelligence and imagination.

Some researchers are sceptical as to whether Victor actually suffered from autism (Lane, 1977). Victor was noted as showing responsiveness to people, flexibility in routine, practical ability, and communication skills which may not be compatible with a diagnosis of autism. Frith (1989) disagrees with Lane by explaining how Victor's competence in these areas does not exclude autism as a possible diagnosis according to what we know about the syndrome currently. Despite his strengths, there was still an element of 'autistic aloneness' in Victor's behaviour, and improvement was slow and cumbersome.

If we accept the case of Victor as an example of autism, then we must address the question of whether social isolation was a primary cause of his developing the syndrome. Frith (1989) mentions several reasons why it is likely that Victor was abandoned when parents might have suspected the child's atypical development. Reports of Victor's appearance by villagers just a few years before his capture suggest he might have been abandoned around 10 years of age. Furthermore, it is unlikely that a very young child could have survived on its own in the wild, especially with a disability. It appears from this evidence that Victor's abandonment was a result of his disorder rather than the cause. Still, it is unknown what fostering Victor may have had up until his desertion. Thus, the question remains as to whether severe social deprivation may result in autistic-like behaviour.

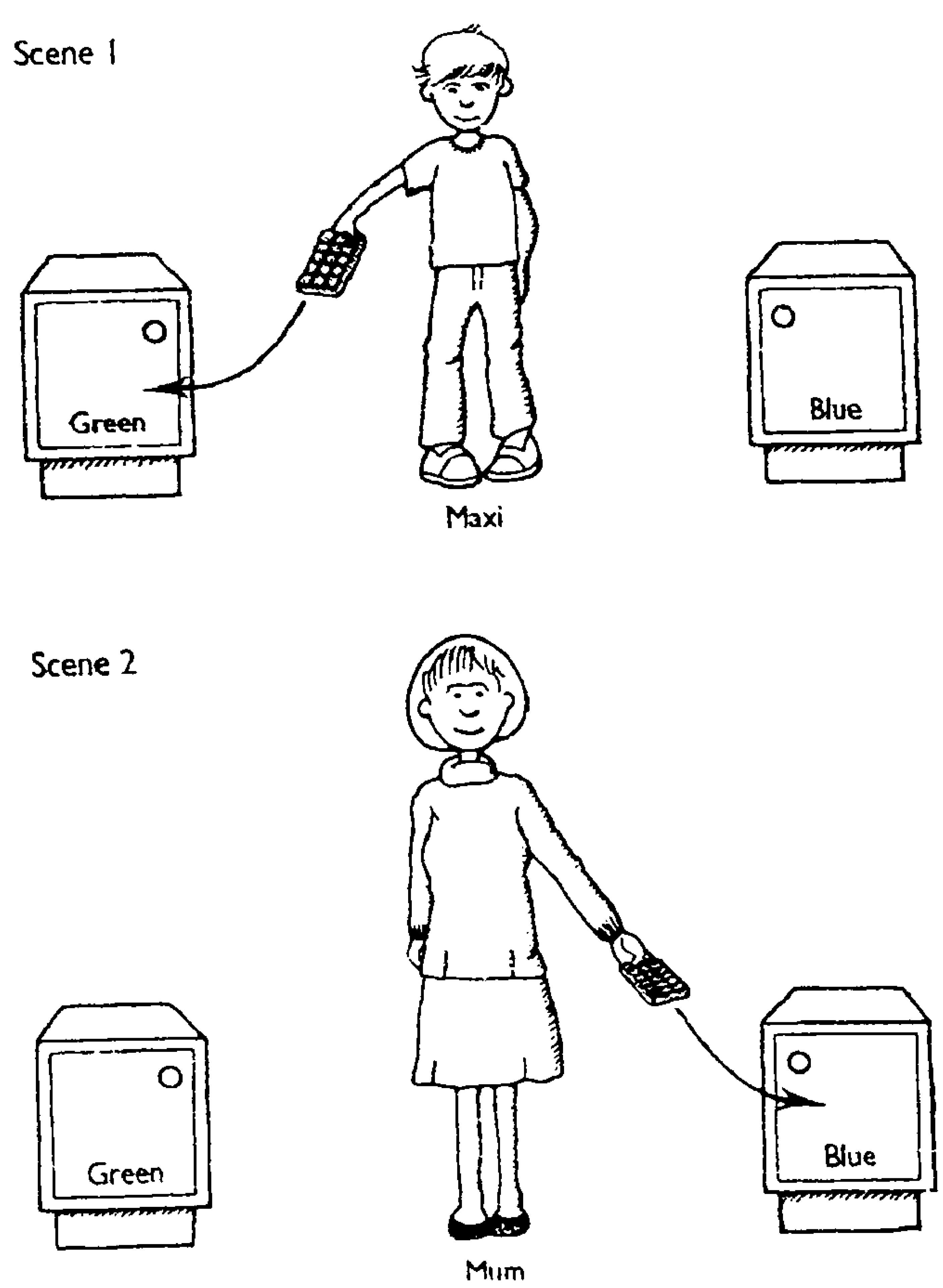
An account of a young girl called Genie sheds some light on this debate (Curtiss, 1977). Genie was documented medically as having normal development at an early age. However, after suffering from years of seclusion in a small room she was discovered at thirteen to have many difficulties including no language. Unlike Victor, Genie adapted quickly to her new environment showing emotional responsiveness and a desire to engage in social play. The case of Genie provides strong evidence that extreme social deprivation does not yield autism. In fact, individuals who suffer from social isolation have been found to have a good chance of recovery (Clarke and Clarke, 1976). This also contradicts early explanations of autism such as 'refrigerator parenting' which assumed parental style was to blame (Bettleheim 1956, 1967). This view is now strongly rejected, especially as no causal relationship between social class or family environment and autism has been proven. This does however provide an example of how notions about the nature and cause of autism have changed since its discovery.

1:6 Theory of mind

One account of autism embraces the idea that the syndrome may be a consequence of a failure to read minds. The notion of theory of mind with respect to typical human development was first put forward by Wimmer and Perner (1983). They presented children with the now widely used unexpected transfer test using play dolls. The story was about a character named Maxi who had placed some chocolate in a green cupboard in the kitchen. After Maxi had left the room his mother enters the kitchen and moves the chocolate to the blue cupboard. Then Maxi who is completely unaware the chocolate has been moved re-enters the room. The children were then asked where Maxi would look for the chocolate. An illustration of this story can be seen in Figure 1:2. Wimmer and Perner found that children aged 4-5 had erred in judging where the ignorant Maxi would look for the object. It was argued that older children were able to do the task successfully because they had developed the ability to represent mental states. This means they could understand that Maxi's belief about where the chocolate would be was different from its actual location in reality. In other words most children over age four could comprehend false-belief. This started off an era of research that was conducted to eliminate other possible explanations of this phenomenal finding.

Figure 1:2

Unexpected transfer test of false belief



In 1985 Baron-Cohen, Leslie, and Frith extended these findings by asking whether children with autism have a theory of mind. They presented a variation of the test used by Wimmer and Perner (1983) to individuals with autism and control subjects. Their test involved two dolls named Sally and Ann. Sally had a basket and Ann had a box. Sally had a marble which she put in her basket when she was finished playing. After Sally had left the room, Ann tranferred the marble to the box. Participants had to judge where Sally would look for her marble when she returned to get it. The results showed that individuals with autism were significantly less successful at this task than controls. Baron-Cohen et al. (1985) concluded that there was a distinctive problem with understanding the mental states of others in autism.

One might rightfully assume that difficulty with the theory of mind task may be due to their failure to comprehend the story or memory problems. However, participants did not have any difficulty recalling that the marble was originally in the basket when asked. Since individuals with autism have learning difficulties, we might also question whether their problems with the task are due to this factor or to their autism. If poor performance is due to low verbal mental ability (VMA) than we would expect other non-autistic individuals with learning difficulties to perform similarly to those with autism. However, Baron-Cohen et al. (1985) included a group of individuals with learning difficulties (Down's syndrome), who despite having slightly lower VMA than those with autism, did not have difficulty passing false belief. This suggests that difficulty inferring mental states is a particular feature of individuals with autism.

A further criticism pointed out by de Gelder (1987) is that failure on a false belief task may be due to difficulties with imagination and make-believe activities rather than inferring mental states. Leslie and Frith (1988) tackled this issue by adapting the unexpected transfer test to a real-life situation. The use of people rather than dolls did not result in better performance in children with autism. Therefore, the methodological criticism proposed by de Gelder was not upheld. Although the theory of mind hypothesis has been very popular as an explanation of autism, the account still has its limitations. A more damaging criticism has been the finding that about 20% of children with autism are able to pass theory of mind tests. Although many in this minority have difficulties with a higher order theory of mind task (Baron-Cohen, 1989; Perner & Wimmer, 1985), there still remain a few individuals with autism who can consistently pass even these tasks (Bowler, 1992; Ozonoff, Rogers, & Pennington, 1991).

Besides the lack of universality found in autism, mentalising deficits are not found to be specific to autism. A study by Peterson and Siegal (1995) presented individuals who were born deaf with an adapted version of the false belief task. Although they had normal non-verbal intelligence, most of this group failed a simple test of theory of mind. The authors concluded that participants' difficulty with the task was a result of them being deprived of a rich linguistic environment. Furthermore, Minter, Hobson, and Bishop (1998) found that individuals who were born blind also had difficulty passing false belief tests. Thus, this shows us that two populations other than those with autism have difficulties inferring mental states.

Together, the above findings seem to undermine the theory of mind hypothesis on the basis of lack of universality and specificity. Although a mentalising deficit is still considered to be a feature associated with autism, alternative explanations have emerged to try to offer a more comprehensive account.

1:7 Executive Function

Although the theory of mind hypothesis addresses the communication, language and social impairments in autism, it has neglected other features of the syndrome. Some of these include insistence on sameness, rigidity in routine, and narrowed range of interests. These difficulties seem to be more associated with attentional focus rather than mentalising. For example, an autistic individual may become so preoccupied with the texture or appearance of a ball that he or she is unable to engage in a game with another individual. The inability to shift attentional focus is referred to as executive dysfunction. Problems with executive dysfunction are characteristic of individuals with damage to the frontal area of the brain. This may result in the perseverance in the current attentional focus or the tendency to be easily distracted by irrelevant stimuli. A couple of tasks, the Tower of Hanoi and Wisconsin Card Sort, have become accepted as standard tests of executive functioning. In the Wisconsin

Card Sort individuals sort cards according to a particular rule (e.g. shape). The person is given feedback as to whether the card was correctly placed or not. Then the rule is changed (e.g. sort by colour) which requires the individual to adapt to a different sorting strategy. It is when individuals have to use a new rule that difficulties with executive functioning become apparent. Those with frontal damage are unable to adopt the new rule and tend to persevere with using the first sorting strategy.

The other test which reveals problems with attentional shifting, inhibition, and forward planning, is the Tower of Hanoi. The task involves 3 pegs and discs of varying sizes. The goal is to transfer the discs on the far left peg to the one on the far right without placing a larger disc on top of a smaller disc. In doing this, only one disc at a time can be moved. Individuals who have a lot of difficulty in performing this task are defined as having executive dysfunction.

These two tasks were used by Ozonoff, Pennington, and Rogers (1991) who wanted to investigate executive functioning tasks in autistic individuals. They found that even those autistic individuals who passed theory of mind tasks, all had deficits in executive function. Individuals with autism showed evidence of preponent responses with perseveration compared to control groups. These results are quite damaging to the claim that a mentalising deficit is the primary cause of autism. They also raised questions about the association between theory of mind and executive function abilities, and whether deficits in executive control may cause problems with mentalising.

Russell, Mauthner, Sharpe, and Tidswell (1991) took on the task of trying to clarify this relationship. They devised the Windows task in which participants are presented with two closed boxes, one having a chocolate reward hidden inside. The goal is for the participant to obtain the reward by pointing to the empty box rather than where the chocolate actually is. Since the individual cannot see in either of the boxes they learn this rule through a preliminary phase of the experiment. They point at random and learn that each time they happened by chance to chose the empty box they were given a chocolate. Then in the next part of the experiment windows on the boxes are opened so the participant is able to see which box has the reward. This task was presented to children with normal development aged 3 and 5 and individuals with autism. They found that children aged 5 had little difficulty pointing to the empty box in order to obtain the reward. However, the children with autism and the 3 year olds were unable to inhibit pointing to the box with the chocolate.

Although this seems to be a clear test of executive dysfunction one could argue that an element of mentalising might be involved because it could involve deception. That is, they have to point to the empty box to prevent the other person getting the reward. Therefore, Hughes and Russell (1993) presented another version of the task which did not involve another person looking in the location that the child indicated. Children with autism still had difficulties with this version of the task which clearly is indicative of a problem with executive dysfunction. Russell et al. (1991) argue that it is this difficulty with executive function that could explain failure on false belief tests rather than problems with mentalising. They say when children are asked where Maxi will look for his chocolate they impulsively react and point to where the chocolate is.

In conclusion, we find that even individuals who pass theory of mind tasks are still impaired on executive functioning. We also know that executive function abilities can account for performance on the standard false belief task. The executive functioning hypothesis therefore seems like a strong contender to help explain autism. However, this theory is not without its criticisms. There are individuals with frontal brain damage that have executive dysfunction who are not autistic. This challenges this theory as an explanation of autism.

Studies by Leslie and Thaiss (1992) and Leekam and Perner (1991) provide evidence that individuals with autism have the executive control capabilities necessary to acknowledge false belief. They presented the false-photo test to individuals with autism and found them to do quite well compared to control subjects. In this task a photo is taken of a doll sitting on a mat. Afterwards the doll is then moved so it is sitting on a box. Children are then asked to judge where the doll will be sitting in the developing photo. As the executive functioning demands posed by the false photo task were similar to that of the false belief task it cannot be argued that the differences across tasks were due to problems in this area. However, the false photo task was different in that it did not require one to infer another's mental state. Indeed, this gives us reason to think that children with autism may have a specific difficulty reading the contents of another's mind after all.

Other criticisms of executive function theory include its vagueness. While there are so many aspects of executive control (e.g.. forward planning, attention switching, inhibition) it is difficult to formulate a coherent idea of the theory. As many of these areas are intertwined it is also difficult to pinpoint if one alone is the primary difficulty or if it is the combination of them. Also, there are still some areas of autism which cannot be explained by executive dysfunction such as exceptional skills found in autism. This theory has contributed a lot towards our understanding of autism, however there is still a great need for further investigation.

1:8 Hobson's account

Hobson (1993) defines problems associated with autism in affective terms. This account differs from the other theories which suggest that autism is primarily due to a cognitive deficit. For instance, the theory of mind account holds the view that ability to infer mental states develops in typical children around 4 years of age. It is the failure to develop a theory of mind which accounts for the social, language, and communication impairments in autism. However, this would suggest that children with autism should not have social or affective difficulties prior to age 4 as this predates the time that a theory of mind has developed.

A study that clarifies this was carried out by Klin, Volkmar, and Sparrow (1992). They carried out a survey on parents of autistic children using the Vineland Adaptive Behaviour Scales. They found that individuals with autism did not reach out in anticipation of being picked up by parents. In children with typical development this behaviour develops around 18 months of age. The failure to respond this way was unique to the individuals with autism and was not found in those with other developmental problems such as Down's syndrome. This poses a problem for the theory of mind hypothesis as it shows evidence of a deficit in socialisation and communication that would originate before theory of mind is believed to develop.

Thus, there seems to be a more basic affective impairment in autism which cannot be explained by the lack of a theory of mind.

Hobson, like Kanner, thought that individuals with autism are impaired in the ability to perceive emotion states in others. He argues that autistic individuals are unable to share experiences with others because they are unaware of the affective perspectives of others. Evidence to support this theory has mainly involved tests exploring the processing of facial expressions (Hobson 1990, 1993, 1994). In a study by Hobson, Ousten and Lee (1988) autistic children were less able to sort faces according to emotions compared to controls when certain facial features were left out. They argued that autistic individuals were less sensitive in emotion perception than individuals with normal development.

A further finding by Hobson et al. (1988) showed that autistic subjects were better than control participants at categorising faces by emotional expression when presented upside-down. It was concluded that individuals with autism may be perceiving the face as a group of individual elements rather than as a meaningful integration of features. If the face were perceived as a whole with a specific orientation, an individual might become confused and under-perform as a consequence. It is suggested that this inability to determine others' affective attitudes is directly related to tardy development in understanding the mind. Other studies also support the idea of a deficit in the socio-emotional domain in autism (Hobson, Ousten, and Lee, 1989). Although many researchers would agree that individuals with autism have difficulties perceiving emotions, the exact nature of this problem is still debated. Specifically, the relationship between Hobson's account and theory of mind is still in need of clarification.

1:9 Limitations of accounts of autism

Although these theories have offered many ideas as to the possible causes of autism, none of them can explain autism in terms of a straight forward single cognitive deficit. The theory of mind and executive functioning accounts have not proven to be specific or universal to autism, while Hobson's theory still needs further investigation.

Another important problem with all these accounts is that they have primarily focused on explaining the main triad of impairments found in autistic individuals. They have neglected other non-social characteristics of the syndrome such as perceptual abnormalities, savant skills, islets of ability, preoccupation with parts of objects, restricted range of interests and excellent rote memory. These features in combination with the other social impairments create an uneven profile of abilities that are unique to the disorder. Recently there has been a substantial increase in the amount of literature pertaining to non-social features of autism. These findings are making it inappropriate to formulate a theory of autism that focuses narrowly on social and communicative impairments.

CHAPTER TWO

Review of the literature: Weak central coherence

2:1 Weak Central Coherence

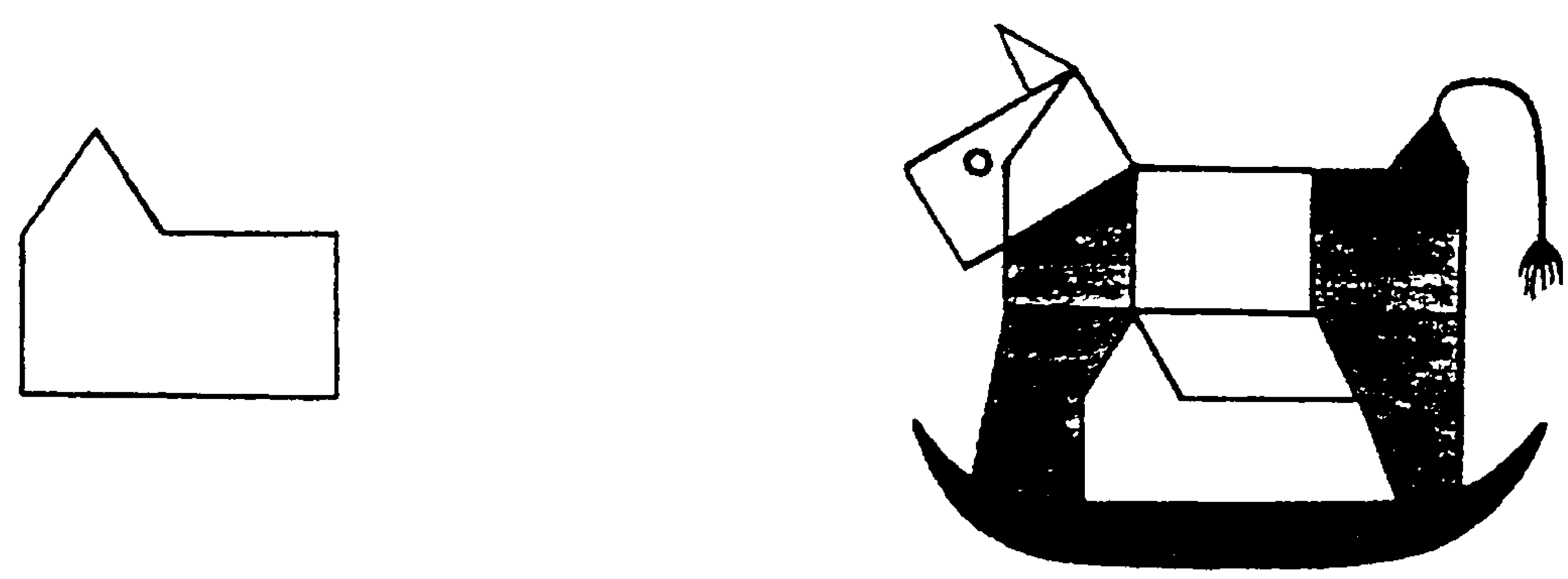
In 1989 a theory was proposed by Uta Frith, which was the first to try and explain the non-social as well as the social features of autism. This theory which is grounded in the information processing literature is known as weak central coherence. Frith explains that 'central coherence' in individuals with normal development involves "the ability to draw together diverse information to construct higher level meaning". Alternatively then, a person with weak coherence would be more likely to process information locally rather than globally. That is he or she would focus on the details rather than attending to the meaningful whole. For, example when watching a movie we may recall the main story line but perhaps forget names or what actors were wearing. Individuals with autism may remember these details, but not be able to comprehend or recall the gist of the movie. This would also mean that they would fail to take context into account when processing information. Frith predicts that those with autism would do poorly on a task which would require the processing of global meaning, but would do well on tasks where attention to detail or component parts was required. This theory may then be able to explain both the assets and deficits in autism as stemming from a single cause at the cognitive level.

2:2 Visuo-spatial tasks

One area where individuals with autism have been shown to excel is on visuo-spatial tasks. Early ideas contributing to the development of a theory of weak central coherence were drawn from research into perceptual abilities in autism. A landmark study by Shah and Frith 1983 found that autistic individuals were superior at finding embedded figures compared to control subjects. The embedded figures test requires an individual to ignore the meaningful more complex figure (e.g. rocking horse) in searching for a smaller figure hidden (e.g. house) within it (see Figure 2:1). Shah and Frith (1983) argued that control participants performed poorly because they were compelled to attend to the global meaning of the stimuli (rocking horse), whereas individuals with autism experienced 'less capture by meaning' and therefore found the task easy. This surprising finding sparked interest into the 'islets of ability' found in autism. In 1993 Shah and Frith found another intact area of ability when they presented individuals with autism with the block design test.

Figure 2:1

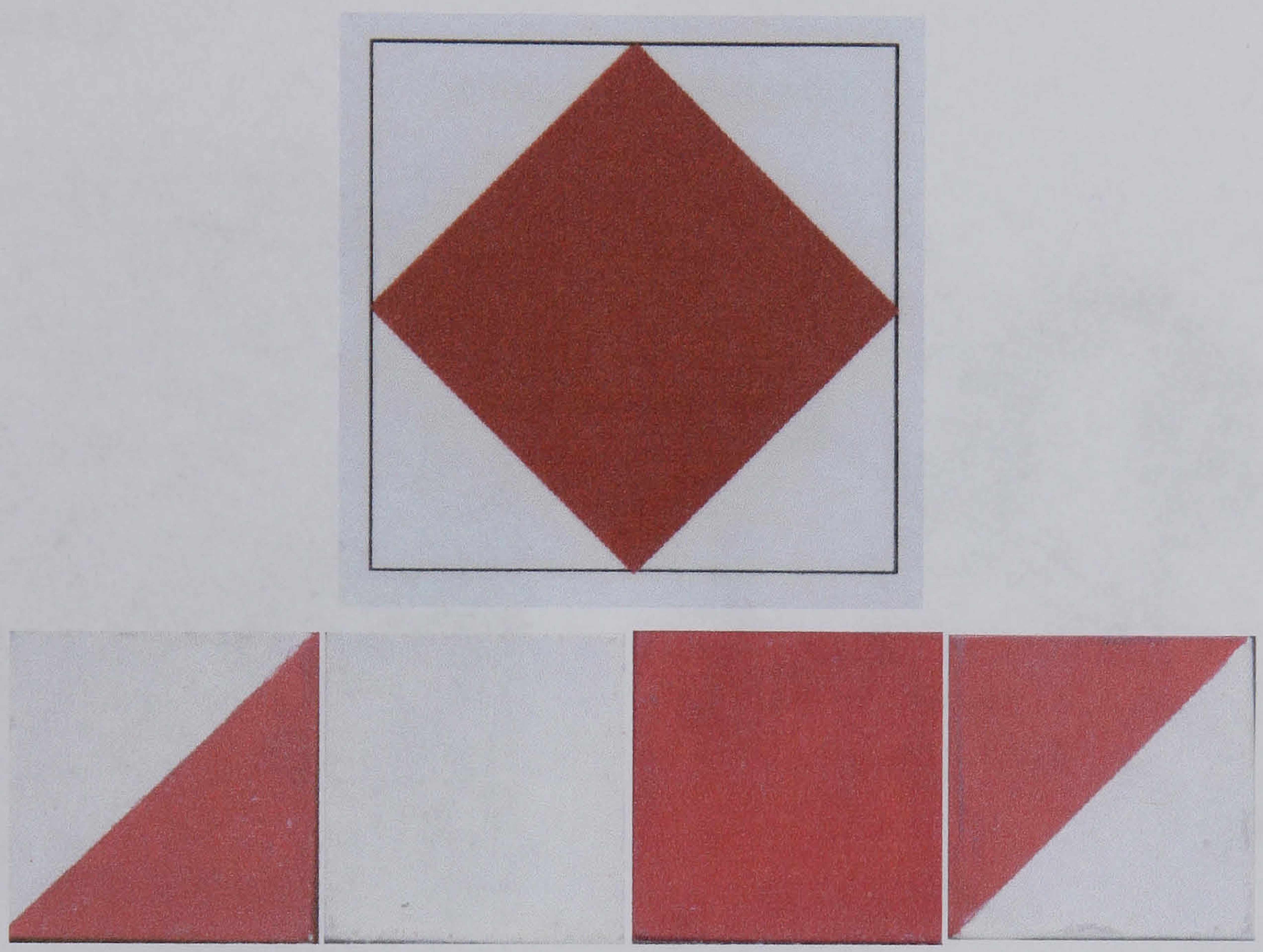
Embedded Figures Test



This test requires an individual to replicate a pattern using individual blocks (see Figure 2:2). Unlike the embedded figures test there is no obvious meaning to the stimuli. The patterns are abstract and not identifiable as any particular object although they do involve regular geometrical forms. Individuals without autism found it quite difficult to recreate the pattern using the blocks. However, when the pattern was segmented their performance greatly improved. In contrast, the individuals with autism performed well irrespective of whether the pattern was segmented or not. This provided evidence that individuals with autism were able to visually segment the pattern into its component pieces quite easily. They argued that these findings along with their 1983 findings with the embedded figures test, offer support for the theory of weak central coherence.

Figure 2:2

Block Design Test

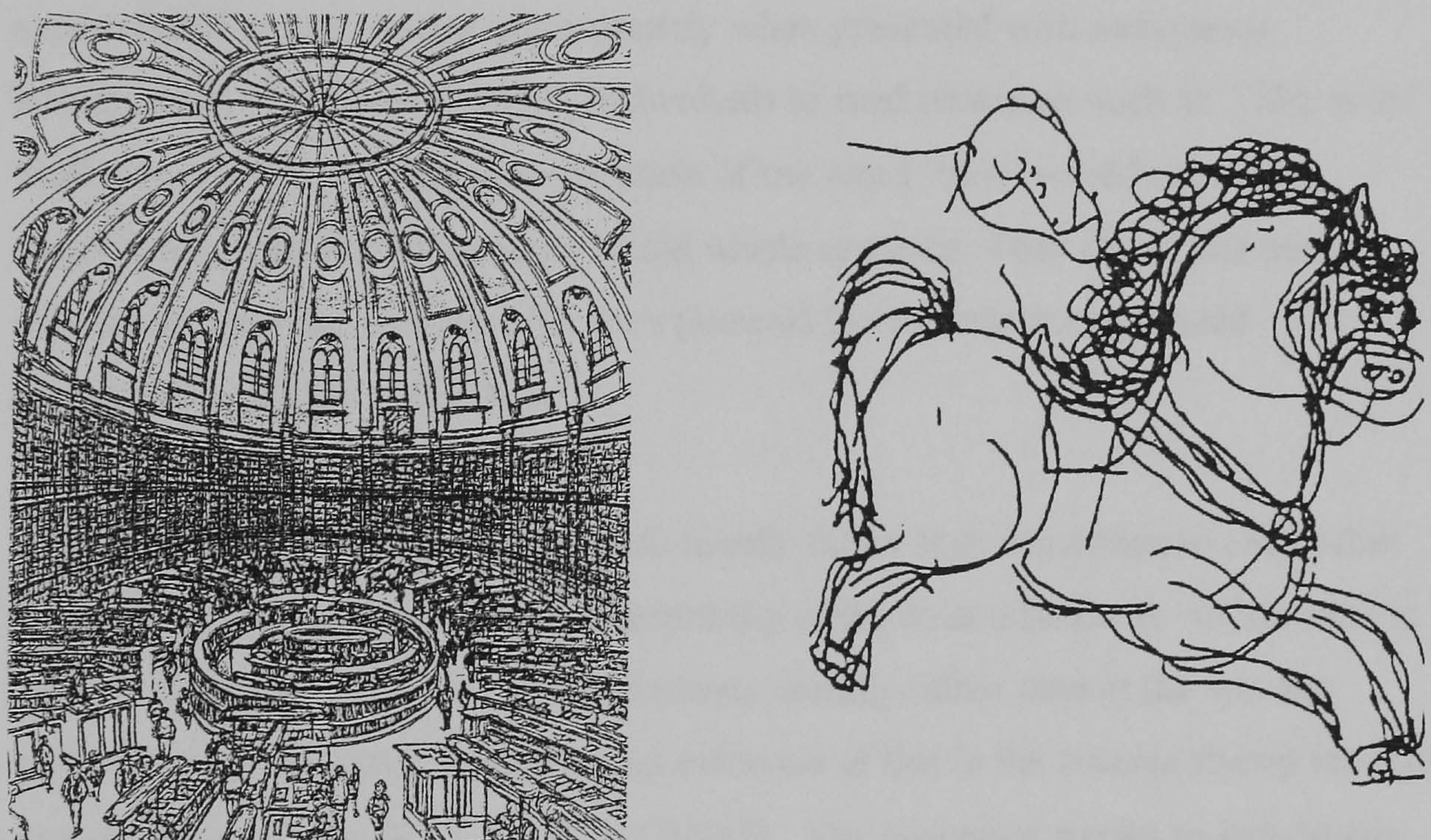


2:2 Savant abilities

As we have already said the theory of weak central coherence stands apart from other accounts because it addresses the prevalence of savant abilities in autism. In the autistic population about 10% of individuals show savant abilities (Rimland & Fein, 1988). Despite having many social and language impairments, they are remarkably talented in a specific domain of knowledge. One ability that has been fairly well researched is artistic talent. The skills needed to draw or paint include being able to visually analyse what one is illustrating. The artist needs to view a scene in its component parts and then build it up piece by piece to form a complete picture. If individuals focus too much on the whole then they might find themselves with a final sketch that doesn't look at all like what they wanted to draw. However, gifted autistic savants seem to be able to break away from viewing a scene in holistic terms, which allows them to paint or draw in a very realistic manner. One such individual who is able to do this is Stephen Wiltshire (Wiltshire, 1987). He is particularly well known for his amazing drawings of buildings, such as the British National library. The precision and realism of his drawings are outstanding. Another famous savant artist is Nadia (Selfe, 1977), who is particularly talented at drawing horses.

<u>**Figure 2:3**</u>

Drawings by savant artists



Although there is quite a bit of literature on savant artistic ability, there are other domains where exceptional skills have been noted such as music or mental calculation. A number of accounts on musical savants have been compiled by Miller (1989). He explains how 12 of the thirteen individuals discussed have absolute pitch. This can be understood in terms of a strong preference to process information locally or in an analytical way which would further support weak central coherence (WCC). There are also those with autism who have phenomenal mathematical skills. A study on one particular autistic individual showed he excelled on tasks such as the Peabody

Individual Achievement Test (mathematics section), the Block design test (WAIS), and the Ravens Coloured Progressive Matrices Test which all involved mathematical concepts (Steel, Gorman, and Flexman, 1984). In contrast, they found him to be significantly impaired on tests of verbal ability.

2:3 WCC and social and language difficulties

The theory of weak central coherence also attempts to explain the social and language difficulties commonly associated with autism. In everyday conversation we encounter many ambiguous words (e.g.sun-son). We need to attend to the context of the sentence in order to know what meaning of the word a person is trying to convey. An experimental study by Snowling and Frith (1986) demonstrated how individuals with autism failed to use context appropriately when presented with ambiguous homographs. They asked autistic individuals to read sentences such as " The actor took a *bow*". The correct pronunciation of the word 'bow' would require an individual to process the meaning of the whole sentence. They found that autistic individuals gave the incorrect (tie on a present) but more commonly used pronunciation of the word 'bow'.

The tendency to process elements individually rather than in relation to each other could also explain their problems interpreting ambiguous utterances. Often autistic individuals are noted to interpret statements literally rather than in the way the statement was intended. Happe found evidence of this in the strange stories task she presented to individuals with autism (1994b). She presented stories to individuals with autism that involved understanding irony, white lies, sarcasm, or jokes. The findings showed that those with autism had difficulty understanding these concepts as they interpreted the speaker's statement in a literal way. The difficulty individuals with autism experienced on this task could be explained as a problem with processing information in context.

Individuals with autism also fail to use contextual information to assist recall of sentences or for related items (Hermelin & O'Connor, 1967a; Tager-Fluseberg, 1991). These require the individual to infer meaning in order to perform successfully. For instance, in a study of free recall of related and unrelated words individuals with autism did better at recall of the unrelated items than controls. However, on recall of the related items they did quite poorly. It seems individuals with typical development make use of the thematic links between the items to facilitate recall while those with autism did not. This failure to utilise meaning has been argued to give support to the theory of central coherence as an explanation of autism.

2:4 Levels of coherence ability

The theory has been criticised for being a bit vague and attempting to explain too much. Happe (1994a) agrees that the theory may suffer from over-extension and that there is need of further investigation. The theory of WCC can be seen as having two aspects, a perceptual and a conceptual level of explanation. A "failure to integrate information in context" can apply to both these levels. Context can either be meaningful (ambiguous homographs) or non-meaningful (block design). Therefore, an individual who displays weak coherence at a perceptual level may be unable to visually synthesize elements to formulate a whole. At a conceptual level an individual with a deficit in coherence may neglect to attend to or apply meaning to what they see. According to Frith's initial account of WCC, individuals with autism have problems with coherence at " higher levels", but not "lower levels" of processing. We can see how a failure to process meaningful context (conceptual level) is related to higher-levels of processing. Skills such as language comprehension involve inferential or abstract processing requiring an individual to perceive the meaningful context. However, the extent to which WCC might affect performance on various activities involving categorisation or memory is still uncertain. Happe (1994a) says that the theory "is perhaps in danger of trying to take on the whole problem of meaning" (page 126).

Agreeing on the level at which perceptual integration occurs is far more difficult. Accumulating evidence suggests there may be deficits at very early perceptual-attentional levels of processing in autism. Some researchers argue that this may be indicative of coherence problems at a much lower level than Frith (1989) initially thought (Happe, 1996; Plaisted, Swettenham, & Rees, 1999). If coherence is weak at a very low attentional- perceptual level, this would carry serious implications for how individuals with autism perceive their world. However, it has also been suggested that deficits in the perceptual domain which appear to be lower-level, may actually be due to problems with higher level processing. We need to differentiate the levels at which coherence is a problem so that we can assess the extent to which WCC explains features in autism. In the following sections we will consider research addressing these issues.

2:5 Information Processing and WCC

As mentioned earlier the theory of WCC is grounded within an information processing framework. Frith (1989) describes a model of the mind that differentiates between central thought processes (global) and peripheral (local) input/output processes. She argues that in autism it is the central processing system, not the peripheral system, that fails to function properly. The peripheral processes are responsible for transforming sensations into perceptions. They are highly specialised modules that deal with various specific domains (e.g. speech). Information that has been processed by the peripheral system is usable at this stage, however it can be sent to the central processor to be interpreted even further. Here information can be compared, reinterpreted, and stored. It is the central processor which allows an individual to draw inferences. If the central processing system is weak, as in the case of autism, then an individual may be unable to draw together pieces of information in order to create meaning. The person is then left with fragments of information that may be of limited use.

The local/global distinction made by Frith (1989) is comparable to "bottom-up" and "top down" processing. Bottom-up processing refers to how we obtain information about our environment directly through our senses. This information can be coded and sent to higher levels within the nervous system. Top down processing can be described as the perception of stimuli involving inferential processes. This includes higher-level functions such as learning, recognising meaningful stimuli, and processing information in context. Solely relying on top-down processing can lead us to make errors in judgements by only perceiving what we expect to perceive. For example, amateur painters often make mistakes in selecting colours for a scene. They may use brown for a tree trunk because they know this to be the colour associated with it. They are often disappointed because of the unconvincing appearance of their tree. In order to create a more realistic looking tree trunk one might need to include purples, greens, or other colours that are less obvious. Likewise, if we are presented with some ambiguous information, we may not adequately comprehend it using bottom-up processing.

Top-down and bottom-up processes must work together in order for effective perception. According to Frith's theory of WCC we would expect bottom-up processing, like local processing, to be intact in autism. However, many researchers in the 1950's and 1960's believed that deficits in lower-level perceptual-sensory systems were a primary deficit in autism. They argued that maybe individuals with autism have problems making sense of the world because information is not registered through the senses to begin with. Several hypotheses were put forward. Among these are the sensory dominance hypothesis (Goldfarb, 1956, 1961; Schopler, 1965, 1966) and the perceptual inconstancy hypothesis (Ornitz & Ritvo, 1968).

2:6 Sensory dominance hypothesis

The sensory dominance hypothesis was popular around the 1960's (Goldfarb 1956,1961; Schopler 1965,1966). This idea proposed that autistic children used proximal receptors more efficiently than the distal receptors. The proximal receptors that include the senses touch, taste, and smell, were associated with early stages of development. On the other hand vision and audition (distal receptors) were thought to develop at a later stage. Given that communication is most closely connected to seeing and hearing, it seemed a plausible explanation for the socialisation and language deficits found in autism. However, contrary experimental findings made it difficult to uphold the sensory dominance hypothesis. In one study Hermelin and O'Connor (1964) presented autistic and non-autistic individuals with stimuli from different modalities. Participants could hear a buzz (auditory), see a light (visual), or feel a gentle tug at their ankles (tactile). They were presented with two stimuli simultaneously, each on opposing sides (left or right). Each child was told that when they saw, felt, or heard a signal, they could have a sweet from the box on the same side. Since two stimuli were always presented together, the child had to select one over the other. The results showed that children with autism, like comparison groups, responded predominantly to the visual stimulus. This fails to support the sensory dominance hypothesis that predicts individuals with autism make better use of proximal receptors. Furthermore, Rutter (1966) found evidence suggesting there may be abnormalities in proximal receptors in autism, such as low sensitivity to temperature or pain. In sum, the sensory dominance hypothesis was difficult to maintain as an explanation for autism.

2:7 The perceptual inconstancy hypothesis

Ornitz and Ritvo (1968) proposed another hypothesis of a more physiological nature. They suggested that there may be problems with the vestibular system which resulted in the inability to regulate sensory input and also with integrating sensory input in coordination with motor output. Difficulties with this hypothesis arose from the vagueness in the terminology involved such as 'perceptual inconstancy' and 'intersensory integration'. So for example, it was unclear what exactly intersensory integration included and at which level it would be deficient. Many of these same criticisms have been a challenge for the more recent theory of WCC. The fact that some low functioning individuals with autism could read aloud gave evidence that they were capable of a certain level of intersensory integration. Also, results from sensorimotor tests (Sigman & Ungerer, 1981) show that autistic individuals could comprehend perceptual constancies such as size and shape. If perceptual inconstancy exists in autism, then we would expect there to be some difficulty with performance on such tasks requiring this type of perceptual judgements. Therefore, little evidence was found to support this argument. In addition, evidence of perceptual abnormalities was found primarily in younger, low-functioning individuals with autism. Thus, these theories failed to account for developmentally advanced autistic children.

2:8 Stimulus Overselectivity Hypothesis

Not long after, another hypothesis based on low-level sensory perception was proposed (Lovaas, Schreibman, Koegel, & Rehm, 1971). The stimulus overselectivity hypothesis suggested that autistic children focus on only one cue in their environment while seeming to ignore all other cues. This idea would help explain why autistic individuals sometimes attend to minor and often irrelevant features in their environment. The stimulus overselectivity hypothesis has been influential in the development of behaviour modification programmes used to teach children with autism. These programmes make use of operant conditioning techniques to help focus the child's attention on other more relevant cues in their environment. There have been some criticisms of this account however, especially in research that has found stimulus overselectivity in non-autistic individuals with mental disabilities (Anderson & Rincover,1982; Gersten, 1983; Koegel & Lovaas, 1978; Litrownik, McInnis, Wetzel-Prtchard, & Filipelli, 1978; Schover & Newson, 1976; Wilhelm & Lovaas, 1976). Therefore, overselectivity was not found to be specific to autism.

2:9 Summary of early research

As the accumulating evidence seemed to indicate that lower level sensory processes were intact, attention was turned towards higher level cognitive processes in autism. Researchers became more interested in exploring the processes behind knowledge acquisition and wanted to know what concepts and skills autistic individuals possess. More recently however, a renewed interest in perceptual abnormalities has emerged. New findings suggest that we may have ruled out the possibility of a deficit at the perceptual-attentional level too soon.

2:10 Autobiographical accounts

Reports from autistic individuals themselves give evidence of perceptual abnormalities in autism (Grandin, 1992; Williams, 1994). These autobiographies offer a valuable insight into the lives of individuals with this disability. One characteristic that is commonly reported by individuals with autism is hyper- and hyposensitivity to stimuli. Evidence of this has been found in all areas such as sound, touch, taste, smell, and vision. Grandin (1992) describes how sounds at a normal volume for others, would be amplified to a painful extent in her ears. She also explains how a simple hug or touch would be a suffocating experience, as her sensory system would go into overload. One way of dealing with the overloading would be to block out everything and withdraw into her own world. Also, people with autism find certain scents or tastes aversive because of their overwhelming intensity (Stehli, 1991). Problems in the area of vision include distorted and blurred eyesight which have been said to cause miscalculations in depth or spatial perception (White & White, 1987). These visual abnormalities in combination with problems in other sensory systems, such as proprioception, may underlie the poor motor control or clumisiness sometimes found in autism. Other anecdotes mention multichannel perceptions or confusion when receiving information through more than one modality at a time.

Although, these firsthand accounts tell us about the inner world of an individual with autism, O'Neill and Jones (1997) argue that there are several problems with relying too heavily on personal accounts. They raise the point that these autobiographies are often written by individuals at the more able end of the autistic spectrum. This creates a certain amount of uncertainty as to how individuals who are less able perceive their world. Another issue they raise is that these autobiographies could be influenced by the interpretation of co-authors or by the popular theories of the day. This may lead to a bias in the way the facts are stated in order to support a certain theoretical standpoint the authors hold. For this reason it is important to rely on other sources, such as psychological research or clinical reports, to learn about the perceptual difficulties associated with autism.

2:11 Clinical Research

Clinical reports include several accounts of autistic individuals showing abnormal responses to sensory stimuli (DeMyer, 1976; Goldfarb, 1961; Hermelin & O'Connor, 1970; Ornitz, 1974; Rimland, 1964; Rutter, 1966). Some autistic individuals are commonly known to notice minute changes in their environment, or find small objects on a patterned carpet. This can be another manifestation of weak coherence in that they are focusing on details rather than the whole of their surroundings. These clinical accounts are often obtained through parental reports, interviews, or questionnaires. A number of studies using these methods have found high numbers of autistic children showing disturbánces in the sensory system (Bettison, 1994; Dawson, 1983; Ornitz, Guthrie, & Farley 1977, 1978; Volkmar, Cohen, & Paul, 1986). However, these types of studies are less systematic and could be susceptible to a certain amount of bias by relying on parental observations. Parents' knowledge that their child is autistic may cause them to incorrectly report autistic tendencies that are not actually there.

Nonetheless, Ornitz (1989) argues that there is strong evidence from clinical studies to suggest that most young autistic children display abnormal sensory perception.

2:12 WCC and lower level perception

Frith (1989) initially proposed that local processing would be intact in autism. She argued that to some extent a "cohesive force" operates at a local level in autism. If coherence were completely absent, even at local levels, then a person would have severely fragmented perception. Some of the clinical and autobiographical accounts do suggest this may be the case for at least some autistic individuals. It could be that coherence is indeed weak at very low-levels in autism. Recently there has been evidence from empirical studies to suggest that this may be true.

Happe (1996) presented individuals with 6 visual illusions and asked them to make judgements about their appearance. She argues this would be a way of testing whether coherence was weak at very low levels, such as perceptual-attentional control. In order to perceive the illusory effect one must view all elements of the stimuli as a whole. Therefore, an individual who processed information locally rather than globally would not fall for the illusion. Surprisingly the results showed that individuals with autism did not succumb to visual illusions, as control subjects had done. These findings were taken as evidence of coherence deficits at low levels in autism.

Further support for this argument comes from a study by Jarrold and Russell (1997). They explored how the theory of weak coherence might affect ability to count canonical forms. They asked individuals with autism, moderate learning difficulties, and typical development to count dots that were either canonical or distributed. The distributed stimuli included black dots randomly spread on a white background with some distracters (white squares). The dots on the canonical stimuli were positioned as they would appear on a dice. Recognition of the pattern of dots in canonical form should allow an individual to state the number without the need to count the individual elements (subitizing). It was expected that control participants would find it easier to count the canonical stimuli resulting in a faster response time. However, if individuals with autism rely on local processing this would put them at a disadvantage when enumerating canonical stimuli.

Their findings showed somewhat mixed support for the theory of weak central coherence. On a group level, performance in the autistic individuals was not enhanced with the canonical stimulus to the extent it had been with controls. However, an analysis of individual patterns of performance found no significant differences between the autistic and MLD groups in regards to the number of global counters in each. Therefore, although there is evidence of difficulties with counting globally in autism, they were not found to be entirely specific to the syndrome in this particular study.

Together these studies offer some support that holistic processing may be deficient in autism at a fairly low level. Both these studies seem to indicate a problem with the basic laws of grouping proposed by Gesltalt psychology such as proximity, similarity, closure, and good continuation (Rock & Palmer, 1990). As grouping has been argued to occur early in visual processing, it is difficult to imagine how an individual could function in life if they failed to use these Gestalt principles. These studies are consistent however with the extremely fragmented perception reported in the clinical and autobiographical accounts discussed earlier. It is possible that coherence may be deficient at a lower-level than Frith initially thought. This idea is challenged by recent findings suggesting that individuals with autism are capable of holistic processing at lower-perceptual levels.

2:13 Evidence suggesting intact holistic processing

Mottron and Belleville (1993) carried out a case study of an autistic savant artist who could process information at a global level. They presented individuals with a hierarchical task to investigate global/local processing of information. This task presents a larger unit (global) which consists of many smaller parts (local). The two levels may be congruent such as a large C made up of smaller C's. In those with typical development information is usually detected more quickly at the global rather than at the local level (Navon, 1977). This finding is typically known as the "global advantage" effect. According to the theory of WCC, if an individual prefers to process information at a local level then they would display a "local advantage" rather than a "global advantage".

However, Mottron and Belleville (1993) found that the autistic savant artist (E.C.) made more local than global errors like control participants. E.C. showed an increase in the number of global but not local errors when presented with incongruent stimuli (a large C made up of small O's). This "interference effect" was not apparent in the non-autistic control participants. The results lead Mottron and Belleville to conclude that individuals with autism process at the global level in a normal way, and the global does not have any special status over the local level. This theory makes different predictions than the theory of WCC. It suggests that individuals with autism are capable of handling visual information at both the global and local levels, however it is the relationship between these two levels which is impaired. Although these findings suggests that holistic processing may be intact at lower-levels, we must keep in mind that they are based on a case study of an autistic savant.

It has been argued that the ability to process globally in autism may be restricted to certain types of procedures. Indeed, there are many variations in paradigms of perceptual hierarchisation tasks that could elicit very different results such as stimuli size, angle, or exposure time (Kimchi, 1992). A recent study by Plaisted, Swettenham, and Rees (1999) demonstrates this by presenting two versions of the Navon task to individuals with autism. They argued that the discrepant findings between Motttron and Belleville (1993) and Ozonoff, Strayer, McMahon, and Filloux (1994) could be due to the nature of the tasks administered. It was proposed that individuals with autism may show local precedence on a divided attention task but not on a selective attention task. A divided attention task was employed in Mottron and Belleville's (1993) study which required an individual to describe a letter at the local or global level on each trial. For instance, participants were asked to press one button if the letter 'A' was present and a different button if 'A' was not present. This would require one to apprehend the stimuli at both a global and local level. In the selective attention task used by Ozonoff et al. (1994) participants had to respond to a target at the local level in one block of trials. They were instructed before a given block of trials to attend to a particular level (global or local). If they were told to attend to the local level they were instructed to press one button if it was an 'H' and the other if it was an 'S'. The results found that individuals showed normal global processing on the selective attention task but not on the divided attention task.

Several explanations were considered to try and account for these results and the difference between the tasks. The most obvious distinction was that in the selective attention task individuals were explicitly told to attend to either the global or local level. On the divided attention task however, they had to search at both the local and global levels simultaneously. Thus, participants were overtly primed in the selective attention procedure but not in the divided attention task.

As a result of these findings Plaisted et al. (1999) suggest that WCC may be thought of as an inability to filter out information at the local level, rather than a deficit in the ability to draw together information to make up the whole. Hyper-activity in channels of local processing may be responsible for the failure to process information globally when individuals are not primed. This is different from Frith's original conception of WCC as it suggests abnormal processing at local levels in how information is received.

Plaisted et al. (1999) also suggest that an individual with autism may voluntarily choose to attend to the local unless instructed to focus on the global level. This implies a 'cognitive style' rather than a 'deficit' since individuals with autism are capable of processing information globally, but they choose not to do so. However, they may attend to the local level only because they find it difficult to shift their attention to the global level as required on the divided attention task. The divided attention task requires individuals to search at one level for the target, then shift their attention to the other level. This would explain the difference in autistic performance on the two tasks, but it would not allow for us to find any advantage or interference effects. Therefore, they concluded that a deficit in attention switching may be enlightening, but it could not explain their findings entirely on its own.

In conclusion, Plaisted et al. (1999) suggest that their results may be explained by more efficient local processing when an individual is not primed, in combination with a deficit in shifting attention to the global level. The study carries implications for both weak central coherence and the hierarchisation hypotheses because it shows individuals with autism are capable of global processing under certain conditions. Although this seems damaging to both accounts, it may just indicate a need for them to be more specific about what circumstances they expect global processing to be a problem. There is still much to learn about these theories, and perhaps new findings in this area may help clarify rather than refute them.

2:14 Higher-level explainations of lower-levels

Perhaps apparent difficulties with perception can be explained at a different level of processing. Frith and Baron-Cohen (1987) argued that many deficits at lower-levels in perception could actually result from abnormalities in higher-level (top down) processing. For example one behavioural characteristic associated with autism is avoidance of eye contact which was has been described by Asperger (1944). He stated, "They do not make eye contact... they seem to take in things with short peripheral glances (page 10, Frith 1989). An important study by O'Connor and Hermelin (1967b) investigated eye gaze in children with and without autism. They presented photographs of a face and a geometric pattern mounted on a black background to participants. Individuals with autism showed shorter fixation times than other groups and spent more time looking at the background. O'Connor and Hermelin argued this to be evidence of abnormal preference patterns in autism. Evidence of abnormal eye gaze behaviour in individuals with autism has also been found in other studies (Mirenda, Donellan, & Yoder,1983; Hutt & Ounsted, 1966). Abnormal eye gaze patterns may seem to be a result of a lower level perceptual deficit. However, some researchers believe that higher level socio-cognitive problems may explain this behaviour. Argyle (1972) argues that eye gaze regulates turn taking during conversation. It may be that eye contact avoidance in autism is due to their inability to understand and apply social rules when interacting.

Brian and Bryson (1996) agree with this line of thinking. They argue that the superior performance of individuals with autism on the embedded figures test could either be due to "less capture by meaning" or "less capture by wholeness". It could be that meaning is less salient to those with autism, resulting in them being able to find the embedded figure easily. However, those with autism might perform well on the task regardless of whether the stimuli were meaningful or not. "Less capture by meaning" would indicate a problem with coherence at higher levels, while "less capture by wholeness" would involve deficits at a lower perceptual level. They varied the meaningfulness of their stimuli to test these alternatives. Although they did not find a superiority effect in the autistic group, their study emphasises the need to consider explanations at different levels. It is necessary to consider "higher" and "lower" processing separately in order to determine where the problem lies so we can make specific predictions using the theory of WCC.

In light of this discussion we might reconsider the argument of deficits in coherence at very low levels. In the study of subitizing by Jarrold and Russell (1997), individuals with autism may have had difficulties understanding the convention of canonical stimuli. Perhaps individuals with autism did not utilise their prior knowledge of the patterns of dots on a die to facilitate counting. Performance could then be attributed to problems with higher-levels of processing. However, in Happe's study (1996) of visual illusions it is difficult to see how a deficit in processing at higher levels might explain why individuals with autism failed to succumb to illusions. In fact relying on one's previous knowledge of illusions might be more likely to result in an individual not falling for the illusion. For instance, a person might say that the two lines within an illusion were the same because they were familiar with how the illusion worked, even if they visually perceived the lines as different. Therefore, evidence from Happe's study may indeed point to a deficit in coherence at low levels, unless most autistic individuals in her sample were not reporting what they truly perceived.

Happe's findings may call for the need to modify the original theory of WCC. Frith acknowledged that to some extent a "cohesive force" operates at a local level in autism. If coherence were completely absent, even at local levels, then an individual would have severely fragmented perception. She assumes that visual illusions operate at low levels. Since those with autism are thought only to have difficulty processing information at high levels, their perception of illusions should not differ from those with typical development:

"Optical illusions are an example of cohesive effects of a specialised input processor, occurring at an early stage of processing. However much we try we cannot escape their influence. A triangle defined only by three dots looks like a triangle even when there are no connecting lines. There is no evidence to suggest that in this respect there would be a difference between autistic and non-autistic children. The difference might lie solely with the cohesive force that acts at a high level in the central processing system" (Frith 1989, Page 97).

Happe's findings are indeed surprising in relation to Frith's original expectations about coherence deficits. Thus, it is important to investigate coherence at low levels to understand more about the boundaries of WCC.

2:15 Conceptual level of WCC

In the previous sections we have argued that there is a need to establish the lowest level at which coherence is weak in autism. However, as we mentioned earlier there is also a conceptual component to the theory of WCC. This part of the theory is also in need of further clarification. The theory argues that individuals with autism fail to process information in context, or fail to integrate parts into a meaningful whole. This explanation remains unclear as the terms "context" and "meaningful" are relative.

As we mentioned before context can either be meaningful or non-meaningful. As in the case of visual illusions the contextual elements, circles and lines, are meaningless. We do not even need to know that these are called lines or circles in order to perceive the distorting effects of the illusory context. If we see a painting depicting an umbrella, a shovel, a towel, a shell, sand, and an ocean, we would be able to identify the location as the seaside. If someone only painted a towel and asked where the scene was we might be puzzled. We need to consider the relationship between the various objects (i.e.things found at the seaside) in order to recognise the picture as the seaside. Likewise, we must consider each word in a sentence in relation to each other (e.g. I would like a glass of water), in order to perceive the meaning behind the utterance. Context is the overall meaning that is built up from all the individual parts. Therefore, an individual who is unable to see relationships between the parts (context) and draw them together may have terrible difficulties understanding their world.

According to the theory of WCC individuals with autism do have an underlying problem processing information in context. However, we would not expect them to have a problem identifying the beach scene or understanding the request for water.

Many empirical studies offer evidence suggesting that "taking context into account" is problematic for individuals with autism. A discussion of these may help us understand the particular situations where difficulties arise.

2:16 Empirical studies suggesting a failure to process meaningful context

Hermelin and O'Connor (1970) found individuals with autism failed to use the meaningful context of the sentence in order to aid recall of word strings. They presented individuals with a list of words, some of which formed a proper sentence (e.g. where-is-the-ship-what-see-was-leaf). Those without autism recalled the sentence no matter where it occurred in the word list, while those with autism consistently recalled the last words on the list. So when the sentence was at the end of the list they did repeat it. If an individual with autism was presented with the sentence "where is the ship?" we would have no reason to doubt they could understand its meaning. However, why would they not recognise the sentence within the word list and recall it? Frith (1989), suggests that the problem may not be with perceiving similarities between stimuli, but with an inability to see the *need* to do this. If we accept this position, then we would say that individuals with autism can process meaningful context, but they simply do not choose to attend to it or utilise it to their benefit. This reinforces the idea of WCC as a cognitive style rather than a deficit.

Findings from a few studies offer evidence in support of a "cognitive style" in autism. As mentioned earlier, individuals have difficulty utilising meaning to assist recall of thematically related words (Tager- Flusberg, 1991). However, in a second part of this study a cue word from a superordinate category was given (e.g. fruit) to the participants. The results showed that with this cue individuals with autism were able to see the links between words and use it to aid recall. The results showed no difference between the clinical and control groups for this condition of the task. Further evidence of a cognitive style comes from a study on ambiguous homographs (Snowling & Frith, 1986). Individuals usually give the incorrect but more common pronunciation of a homograph because they fail to take the context of the sentence into account. However, Snowling and Frith found that with some training the individuals with autism were able to give the correct response. Therefore, it is not an inability to process information in a particular way, rather it is a stylistic preference of the individual. We might ask why things we perceive as most salient or important in our environment are not so obvious to individuals with autism.

2:17 Meaning and attention

It may be that individuals with autism do not attend to the same things in our environment as we do because they do not hold the same meaning. Snyder and Barlow (1988) argue that what we perceive in our visual field conforms to certain patterns. Our perception can be more efficient if we have certain expectations of what we are to see. Snyder and Thomas (1997) suggest that typically developing individuals have mental representations that pick up on the salient or ecologically significant aspects in the environment. If we do not impose certain expectations on what is to be seen then we might perceive all details as equally important.

A study by Weeks and Hobson (1987) explored the salience of emotional expression in individuals with autism. They showed participants photographs of people which could be classified according to hat type, emotional expression, sex, and age. According to Hobson, those with autism have an impairment in understanding affective attitudes. He would then predict that emotional expression would not be paramount as a criterion. Indeed, when autistic individuals were asked to sort photos any way they like, they used hat type as a strategy. However, when asked again to sort according to another feature they were able to sort according to facial expression. In contrast, the majority of children without autism sorted according to facial expression before hat type.

According to the theory of WCC we might argue Hobson's findings are not necessarily a problem with processing affective expression, rather they suggest a more general problem with "less capture by meaning". The fact that the individuals with autism were able to sort by facial expression when given a second chance demonstrates they are able to recognise emotion. We might ask whether individuals attend to different aspects of a scene that are non-social in nature.

The theory of WCC is powerful in that it has been able to account for many of the strengths and weaknesses associated with autism. It is capable of explaining atypical behaviour at different levels of processing, although these levels are in need of further investigation. We have also argued that WCC is a "cognitive style" rather than a deficit. This raises the question "To what extent can a difference in cognitive style explain general features of autism?".

2:18 Theory of Mind and WCC

Initially Frith (1989) suggested that weak central coherence may account for impairments in theory of mind. However, more recently it has been argued that deficits in coherence ability may be additional and separate from problems with mentalising. Evidence to support this comes from a study by Happe (1991) where she presented autistic individuals with a battery of theory of mind tests as well as a homograph reading test. She found that even those who consistently passed all theory of mind tests still failed to use the context appropriate word on the homograph reading task. This provided evidence that the relationship between mentalising and coherence ability was not causal.

Further support for this comes from another study by Happe (1994c) investigating theory of mind and performance on the WISC-R and WAIS (subtests). She found that individuals with autism who failed theory of mind tasks also had difficulty with the comprehension subtest. However, they did very well on the Block Design Task (non-verbal performance) regardless of their mentalising ability. Happe (1994b) presented autistic individuals with a more naturalistic version of the theory of mind task. Even those who passed second order false belief tests had difficulty inferring information from a story. Weak central coherence might then help account for impairments in those individuals with autism who are able to pass false belief tasks. This suggests that there may be two different cognitive deficits that underlie autism rather than a single factor. These findings would be compatible with the idea that theory of mind is a modular ability which relies on a fixed neural network which is domain specific (Fodor, 1983). Baron-Cohen and Leslie (Baron-Cohen, 1995; Leslie, 1987; Leslie & Roth, 1993; Leslie & Thaiss, 1992) have argued in support of this view. If we assume the ability to mentalise is domain specific, then we would not expect it to be linked with other abilities such as weak central coherence.

However, studies employing more complex mentalising tasks and tests of central coherence have suggested there may be a link between the two abilities. Some evidence for this comes from a study by Baron-Cohen and Hammer (1997). They tested 30 adults with typical development and 30 parents of children with Asperger's Syndrome with an equal number of males and females in each group. The embedded figures test was employed as a test of weak central coherence, while the eyes reading task was used as a measure of mentalising ability. In the 'eyes' task, participants were presented with photos of the eye region of the face only. After a few seconds the picture is removed, and the individual is asked to choose which of two words best describes what the person is thinking or feeling (e.g. sad or happy). They found a significant sex difference in performance on the two tasks, with the males doing better on the embedded figures test and worse on the 'eyes' task than females. Baron-Cohen, Joliffe, Mortimore, and Robertson (1997) also found a sex difference on the 'eyes' task in their study. Together, these findings suggest that theory of mind and WCC abilities may not be as independent as we thought. They also suggest that the inverse relationship between these abilities found in the male population is even more pronounced in autistic individuals.

Is it plausible to think that two such distinctly different abilities could be related in some way? One might ask whether the tasks used in these studies are actually testing what they are supposed to. For instance, can we be assured that the success on the 'eyes' test relies primarily on mentalising ability? Jarrold, Butler, Cottington, and Jimenez (1999) argue that this task may not be a valid test of theory of mind for several reasons. They say that the 'eyes' task involves representation of an agent's attitude but not the content of that attitude. For instance, one might be able to tell whether one's eyes appear happy or anxious, but they could not infer the reasons behind these emotions. Many would argue that the representation of both attitude and content is needed to qualify as metarepresentational ability (Perner, 1991; Jarrold, Carruthers, Smith, Boucher, 1994). Therefore, the 'eyes' task may not be regarded as a pure test of theory of mind.

In fact, there may even be a component of central coherence involved in the task as Jarrold et al. (1999) point out. They argue that one needs to visually integrate the various cues (e.g. angle of eyebrows, direction of gaze) in order to perceive the mental state behind the eyes. If any of these cues were processed in isolation we might expect one to be less accurate in their judgements on the task. This would explain why an individual with a local processing style would do poorly on the 'eyes' task and well on the embedded figures test.

Jarrold et al. (1999) made attempts to investigate the relationship between WCC and theory of mind by using theory of mind tests that were not visual in nature and were accepted as a true test of metarepresentational ability. Several measures of theory of mind were administered as well as two tests of central coherence. The results revealed significant correlations between these two abilities, which remained when verbal mental ability was accounted for. Thus, the relationship found between theory of mind and WCC can be explained in terms of individual differences rather than developmental differences.

2:19 Executive function and WCC

We have already discussed the possibility that characteristics of autism may result from impairments in executive functioning. A number of abilities are considered to be under executive control that we may also find in areas such as theory of mind and weak central coherence. In our pursuit to understand more about WCC, we must clarify how it differs from executive functioning. Frith and Happe (1994) argue that the two theories do make distinctly different predictions. They suggest that "inhibition of pre-potent but incorrect responses" may have two components (inhibition and recognition of context-appropriate response). It may be that individuals have problems with inhibiting action only when context is relevant. This would show difficulties with processing context, as the theory of weak central coherence would predict. However, it could be that autistic individuals have problems inhibiting action even when context is irrelevant. This would suggest a more fundamental problem with inhibitory control in general, as predicted by the theory of executive dysfunction.

Recently, studies on perceptual ability and attention in autism have considered the role of executive dysfunction more closely. This research is of considerable interest because it allows us to understand more about the overlap between executive functioning and weak central coherence. As mentioned earlier, attention shifting is an executive ability that is thought to be impaired in autism. Impairments in shifting attention can be linked to "tunnel vision" which is reminiscent of earlier perceptual theories of overfocused attention (Lovaas, Schreibman, Koegel, & Rehm, 1971; Rincover & Ducharme, 1987). If an individual is intensely focused on a particular stimulus, they may not be able to disengage their attention to look elsewhere even when a task requires them to do so. Evidence of this has been found both within the visual modality (Casey, Gordon, Mannheim, & Rumsey, 1993; Townsend & Courchesne, 1994; Wainwright-Sharp & Bryson, 1993) as well as between visual and auditory modalities (Courchesne, Akshoomoff, & Ciesielski, 1990).

Of particular interest however, is a study by Wainwright and Bryson (1996) looking at visuo-spatial orienting in autism. They presented 3 different experiments to high functioning adults with autism. The first task required participants to detect a single target that would appear either on the left or the right side after an initial fixation cue in the centre of the computer screen. The participants were required to press a button as soon as they saw the stimulus which then recorded their response time in seconds. Typically, individuals with normal development would show a left field-right hemisphere advantage for attending to stimuli. The researchers were interested in whether or not the same would be true of those individuals with autism. Indeed, the results showed that autistic individuals, like controls, had a typical left visual field advantage.

The second experiment was exactly the same except stimuli could appear at the centre as well as to the left and right of the screen. In this experiment those with autism performed differently than controls in that they responded more quickly to central than to lateralised stimuli. Moreover, the left field advantage previously found in the first experiment disappeared. Difficulty disengaging focus from the centre of the screen was taken as evidence of overfocused attention in autism. In the final experiment the processing demands of the task were increased which required a participant to identify as well as detect a target (i.e. a cross).

The results of this experiment indicated that the advantage of central over lateral targets was enhanced in autistic individuals even further with the additional requirement of identification. In controls however, the left field advantage disappeared. These findings together support the idea that individuals with autism have problems shifting their attentional focus through space. Furthermore, as a result of this difficulty with attention shifting they might be less able to handle additional processing demands such as target identification in the final experiment.

Again, it is important to note that slight changes in the procedures of the 3 experiments yielded different results in the autistic group. In the first experiment, autistic individuals showed the normal left field advantage like controls when detecting the target. It is only when the additional central target is added in Experiment 2 that this advantage disappears in autistic individuals. The autistic group may experience difficulty disengaging attention from the fixation point to the lateral target, which controls are able to do more quickly. Thus, if those with autism were overly focused on the centre of the screen after the fixation point was displayed this would allow them to detect the central target more quickly. Even though they detected the left field target more quickly than the right in the first experiment, the autistic groups' mean detection time was still much slower than the controls.

We could perhaps compare this to the global/local hierarchisation task discussed earlier. In the study by Plaisted et al. (1999) those with autism show a normal global advantage on a selective attention task, but not on a divided attention task. The researchers argued that problems on the divided attention task may be due to difficulty switching attention to the global level after initially searching at the local level for the target.

Another study by Plaisted, O'Riordan, and Baron-Cohen (1998a) explores these issues further. They argue that overselective attention may underlie problems with transferring newly acquired skills in autism. They presented adults with autism and controls with a perceptual learning test. This involved recognising patterns on a screen which were composed of seven beachball like circles. Three of the seven circles were always in the same position, however the remaining four were in different locations for each stimulus. They anticipated that those with typical development would be better able to discriminate pre-exposed stimuli than they would non-pre-exposed stimuli thus showing a perceptual learning effect. For the autistic group they proposed that individuals would be better at processing unique features than common features between stimuli. Thus, participants with autism would not be expected to show a perceptual learning effect. The results did indeed support the predictions.

Plaisted, O'Riordan, and Baron-Cohen (1998a) argue weak central coherence cannot account for their pattern of results. They remark that the global pattern differed for each of the stimuli. Thus, perception of a global pattern by the control group would predict a weak rather than a strong effect. Since they did find a strong perceptual learning effect in the control group, they concluded that performance was not based on the perception of the overall pattern.

Alternatively, they suggest that there may have been a problem shifting attention between different stimuli. In order to discriminate between two stimuli one needs to search the screen to find differences in the relative spatial positions of the circles. If individuals with autism restrict their attention to just one particular area and do not visually search the other parts of the screen then this might explain their poor discrimination of pre-exposed stimuli. Plaisted, O'Riordan, and Baron-Cohen (1998a) argue that this cannot however explain the better performance by individuals with autism by the end of the preexposure phase and in the non-preexposed condition. Therefore, they propose a new hypothesis of reduced generalisation which can account for this. The hypothesis suggests that individuals with autism are good at processing unique features of a stimulus, but are poor at processing common features compared to those without autism. In conclusion they suggest this new hypothesis in combination with reduced attention switching may account for their findings. The results of this perceptual learning study are important in that it shows an area those with autism excel in (enhanced discrimination of novel stimuli) which cannot be accounted for by the theory of weak central coherence. This suggests a need to consider more carefully alternative explanations to WCC when investigating perceptual differences in autism.

2:20 Why study WCC?

The extent to which WCC can account for symptoms of autism is still under debate. Although other theories have so far failed, it is possible the theory of WCC may be able to explain all features of the syndrome (social as well as non-social features). However, the more likely alternative is that autism involves "weak coherence" in addition to other deficits such as mentalising or executive dysfunction.

As we have seen, a large amount of research pertaining to WCC focuses on perceptual abilities in autism. One might argue that understanding perceptual abnormalities is not vital for our understanding autism as it is not a "core" impairment. Although severely atypical perception is not evident in all individuals with autism, abnormalities in perception may exist to a lesser extent in the general clinical population. For example, in a population of 20 individuals with autism we may find that all excel on the block design test, however only a few might have severely fragmented perception. These few might even fail to succumb to illusory effects. This would also be supportive of the idea that "weak coherence" is a cognitive style that varies within a population as well as between populations. Nonetheless, perceptual abnormalities are certainly more common in autism than in other developmental disorders. Advances in perception research may reveal areas of dysfunction that we could not detect with less refined theories and with the outdated technology used in earlier years.

I have also discussed how the theory of WCC attempts to explain the more primary impairments found in autism such as language and socialisation. This has been referred to as the component of the theory that involves conceptual knowledge. More research is needed at this level to specify which areas would be affected by "a failure to take context into account". Almost everything involves context to an extent. Evidence suggests that those with autism are able to use contextual information under some circumstances. This area needs to be investigated so that we can better understand under which conditions individuals with autism fail to process information in context. Only by doing this will we be able to understand the exact nature of the problem individuals with autism have with attending to "context".

CHAPTER THREE

Do individuals with autism and Asperger's syndrome show weak central coherence at low levels?

This chapter is a modified version of the paper by Ropar and Mitchell (1999), "Are individuals with autism and Asperger's syndrome susceptible to visual illusions?", published in the Journal of Child Psychology and Psychiatry, 40, pp.1283-1293.

3:1 Coherence at very low levels

In chapter two I discussed the evidence for a deficit in coherence ability at lower perceptual levels. It seems that most individuals with autism are able to perceive information from their environment (Frith & Baron-Cohen, 1987). For instance, they can identify pictures, objects, or sounds. They can even translate information across modalities as evidenced by their ability to read aloud. Nonetheless, there is sufficient counter-evidence from experimental studies as well as clinical reports to suggest that individuals with autism may have problems integrating information at lower perceptual-sensory levels. Among this evidence was a study by Happe (1996) which found individuals with autism to be less susceptible to visual illusions. She argues that coherence may indeed be weak at very low levels. Her findings contradict Frith's initial predictions about the level at which coherence is weak. Happe's study may indicate a need to re-define or extend the theory of WCC to account for her findings. Therefore, it is essential that Happe's findings be replicated using more sensitive measures of illusion susceptibility in order to know the lower boundary at which we might find weak coherence in autism.

Experiment 3:1

3:2 Introduction

The results of a study by Happe (1996) suggest that individuals with autism might be less susceptible to visual illusions than those with typical development. In her study, participants inspected a variety of lines and shapes presented in a context that affected illusory distortion. Participants were invited to judge whether two lines or shapes were the same or different in size, or were asked if a line was straight or curvy. As expected, those with typical development were susceptible to the illusions, and judged, for example, that two lines of physically identical length were different. In contrast, significantly more participants with autism made judgments about the stimuli in accordance with their physical properties. Participants with typical development benefited from having the stimuli pre-segmented with added colour and depth, whereupon they were less likely to succumb to the illusion. Individuals with autism gained no such benefit because their judgments were already at or near ceiling in the condition without pre-segmentation. If individuals with autism are not susceptible to visual illusions, then the implications are profound. Since the effects probably stem from basic perceptual processes, it is possible that an individual who was not susceptible would be perceiving the world in a radically different way.

Happe (1996) explained her remarkable finding by suggesting that participants with autism might have "weak central coherence" at a basic level, such that they did not perceptually integrate the target stimuli with the visual context. The hypothesized failure of integration might thus neutralize the effect of context. In Happe's study, participants made verbal judgments about the stimuli. In the current research, I question whether the effect would also be apparent with nonverbal measures. I begin by considering Happe's finding in relation to the hypothesis of weak central coherence and with respect to aspects of perceptual functioning in people with typical development and with autism.

There are many anecdotal reports of unusual experiences of perception in autism, which generally indicate heightened awareness of the fine detail of a scene. For example, one child reputedly was able to find small objects on a patterned carpet more rapidly than an individual with typical development (Frith & Baron-Cohen, 1987). There are also reports of savant artists who demonstrate outstanding drawing ability without ever having formal artistic training (Selfe, 1978; Wiltshire, 1991). Investigation into these special abilities has suggested that individuals with autism have certain perceptual characteristics which may actually be an advantage on some visuo-spatial tasks.

Supporting evidence was reported by Shah and Frith (1983), who presented an embedded figures task and found that individuals with autism were able to locate a target hidden within a more complex figure more accurately than control subjects. In a later study, Shah and Frith (1993) presented a block design task, in which blocks with parts of a design on one face have to be assembled to recreate an entire pattern. Once again, autistic subjects completed the task more quickly and with fewer mistakes than individuals with typical development. While children with typical development benefitted from seeing the target design pre-segmented, those with autism performed well whether the design was pre-segmented or unsegmented. The finding suggests that those with autism differed from other participants in that they were easily able to apprehend the target shape in its component parts even when presented as an unsegmented whole. These areas of preserved functioning have been referred to as "islets of ability" by Kanner (1943). The superior performance of autistic individuals on these tasks has been explained by Frith (1989) to arise from "weak central coherence".

Weak central coherence has been described as showing a preference to process information locally rather than globally, or a failure to process information in context (Frith 1989). This stands in contrast to perception in individuals with typical development, where global analysis takes precedence over local (Navon, 1977). Global precedence might be uniquely human, since Baboons actually show preference for local perceptual processing. In view of this, Fagot and Deruelle (1997) suggest that global precedence in humans might not have a purely perceptual or sensory basis. Frith's theory explains autistic success on various visuo-spatial tasks such as the embedded figures, where weak central coherence seems advantageous (Shah & Frith 1993;1983). Autistic individuals with weak coherence will not be captured by the global shape, which will free them to focus on the individual lines and thus detect the hidden shape swiftly.

Having weak central coherence is often a disadvantage, of course, and it could be responsible for difficulties in some aspects of impaired reading comprehension. A study by Frith and Snowling (1983) suggested that autistic individuals failed to take account of the sentence context when reading ambiguous homographs. Subjects were asked to read sentences like, "He took a bow when everybody clapped". The autistic subjects tended to give the more common pronunciation of "bow" (as a way of fastening a shoe lace). Although the theory of weak central coherence has been fairly successful in explaining both the deficits as well as the assets found in autism it is unclear at which level of processing coherence is supposed to be weak.

Researchers have not been able to find much evidence of a deficit in lower level processing in autism (Hermelin & O'Connor, 1970). A review by Frith and Baron-Cohen (1987) concluded that any perceptual abnormalities should be explained in terms of higher levels of intellectual functioning. They claim that basic processes are sufficiently intact to allow depth perception and separation of figure from ground. If aspects of low-level perception are not affected by autism, then we would expect individuals to be susceptible to visual illusions, since these are thought to occur at a low level of processing (Robinson, 1972; Bruce, Green, & Georgeson, 1996). Consistent with this, Mottron and Belleville (1993) reported the case of EC, a savant artist with Asperger's syndrome, who showed precisely the same susceptibility as controls to a selection of visual illusions, including the Hering, the Ponzo, the Poggendorf and the Muller-Lyer. The illusory effect was apparent in both a verbal and nonverbal measure. In the verbal task, E.C. was asked which line looked the longest, and he reliably indicated the line which merely appeared longer. In the nonverbal measure, E.C. was asked to draw the stimuli, and the illusory effect was evident as a systematic distortion in his drawings.

Despite research against the idea of a deficit in lower level processing, several clinical accounts give a strong indication that perceptual differences do exist in autism. Jolliffe, Lansdown, and Robinson (1992) report how one autistic person describes her difficulties looking at people and pictures. She explains, "I am not looking at the whole but rather just the outline or the part. I cannot look at a picture completely, but only a small section at a time" (Jolliffe et al. 1992, p.15). There are also reports of autistic individuals having difficulties with depth perception when attempting to go down a staircase (Grandin, 1995). Similarly, Donna Williams (1992) recalls numerous visual abnormalities throughout her autobiography. Given the clinical reports, in conjunction with a reasoned account of how weak coherence could affect the basic functioning of perception, Happe (1996) thought it worthwhile to conduct a systematic study into autistic susceptibility to visual illusions. She pointed out that in an illusion like the Ponzo, the context of the converging lines is responsible for provoking the perceptual distortion of the stimuli circles (see Figure 3:1). If an individual were effectively able to ignore this context, then the illusion would not work. Since individuals with autism are reputed to fixate locally rather than globally, owing to weak central coherence, they may not be influenced by the wider context and thus would not be susceptible to visual illusions. In Happe's study, individuals were presented with 6 common visual illusions and asked questions about their appearance. For example, they were asked whether two circles appeared the same or different or if two lines were straight or curvy. The results showed that individuals with autism were less susceptible to some of the illusions than control groups.

It is important to replicate Happe's (1996) study to establish whether the same results could be obtained with a different kind of measure. Perhaps her participants with autism had already been acquainted with visual illusions and judged according to what they knew rather than what they saw. Moreover, it is possible that the difference between individuals with and without autism is confined to a task that requires a verbal response. In Happe's study, participants would be scored correct (i.e. not susceptible to illusions) if they responded "same". Differences between groups might thus have reflected variations in a verbal response bias for judging "same". Apart from this, it remains an open question whether variations between samples would appear at the level of manual response. Aglioti, DeSouza, and Goodale (1995) report differences in susceptibility to visual illusions according to whether the participant is asked to make an explicit judgment of size or to reach out in order to pick up the illusory stimulus. I return to this point when introducing Experiment 3:2.

The purpose of the current study was to replicate Happe's (1996) findings using a more quantifiable measure of illusion susceptibility at the level of manual response. A computer program was developed to graphically illustrate 4 different illusions (see Figure 3:1). All were illusions of extent in that they operated on the basic principle of size constancy (Day, 1972; Robinson, 1972). By asking the subjects to adjust the length of lines, or size of circles, the strength of the illusion could be quantified. Furthermore, presenting the illusions graphically and asking for manual judgments would help avoid some of the biases that can occur with verbal responses. A group with Asperger's syndrome were also included to see whether individuals with autistic features but with less severe learning difficulties are susceptible to illusions.

3:3 Method

Subjects. Twenty-three males with autism and 13 males with Asperger's syndrome took part in the study. All had been diagnosed by experienced clinicians according to standard criteria (DSM-IV, American Psychiatric Association, 1994) and attended schools for children with special needs. Their verbal mental ages were assessed using the British Picture Vocabulary Scale (Dunn, Dunn, Whetton & Pintilie, 1982). Due to constraints at the school, 3 of those with autism were not tested on the Titchener and Hat illusions (and their controls). A further 2 were not tested on the Hat illusion only (and its control). One child was not tested on the Muller-Lyer illusion only (and its control). In consequence, the n values and df vary in the results section, depending on which illusion is being considered for analysis.

A group of 17 individuals with moderate learning difficulties (MLD) were approximately matched to the mean verbal mental age of the autistic group. This group was of mixed aetiology but without any autistic-related problems. Three groups of individuals with typical development were also included in this study. One group of 20 children had a mean age of 8 years and 3 months, which was fairly close to the mean verbal age of the autistic group. Twenty-one children between 10-11 years and 15 adults were also tested. Table 3:1 provides details.

Table 3:1

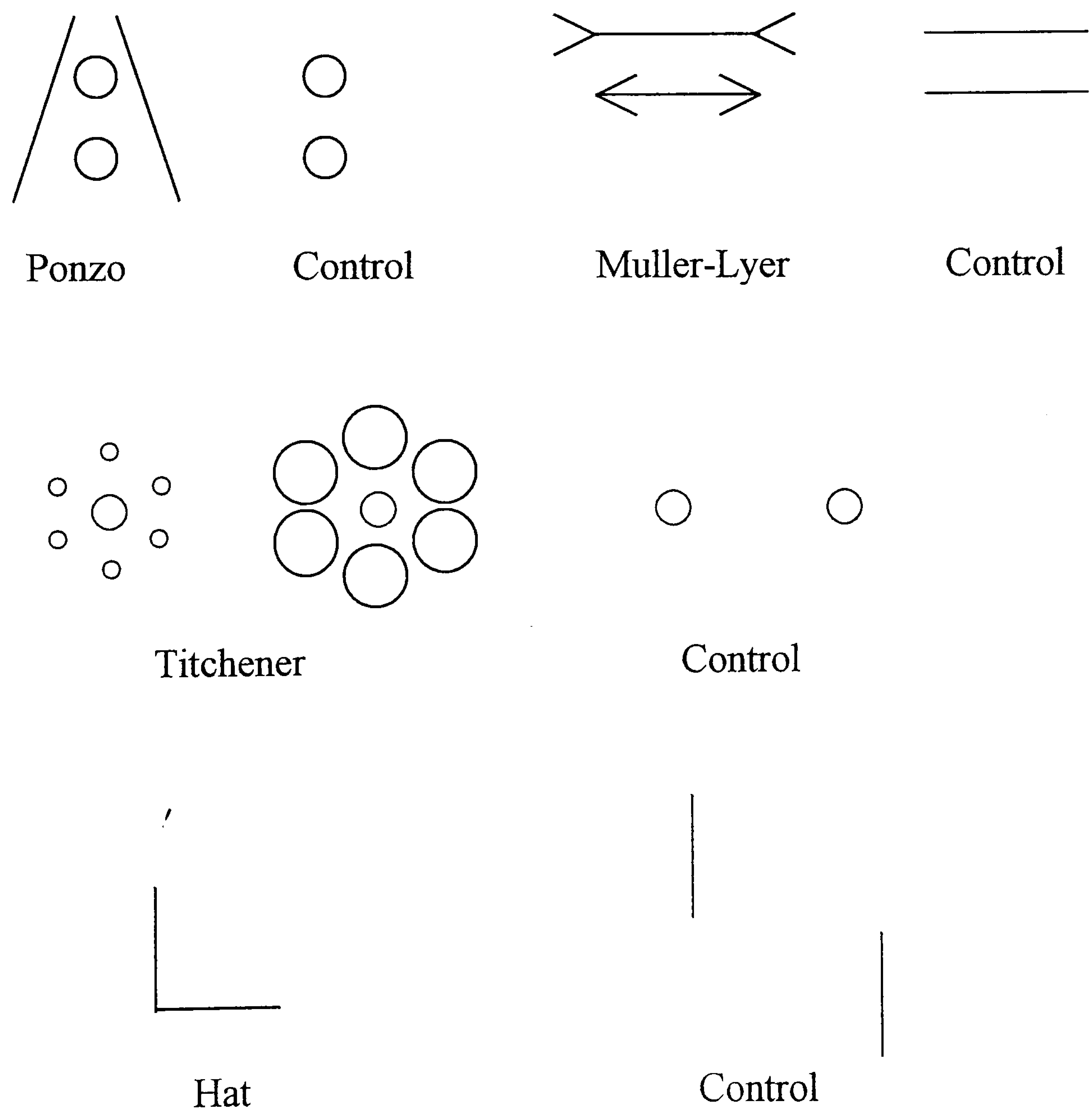
Subject characteristics for Experiment 3:1

Group	N	CA (y;m)	VMA(y;m)	BPVS Standardized score (VIQ)
Autism				
Mean	23	13;0	7;2	59.9
SD		3;8	2;10	19.1
Range		(7;10-18;4)	(4;1-14;3)	(40-84)
Asperger's				
Mean	13	14;2	14;7	97.5
SD		2;8	4;7	9.9
Range		(9;5-17;8)	(7;9-19;6)	(68-126)
MLD				
Mean	17	10;7	6;1	61.5
SD		0;4	1;4	7.8
Range		(9;11-11;4)	(3;5-8;7)	(40-84)
Year 3				
Mean	20	8;3		
SD		0;3		
Range		(7;8-8;8)		
Year 6				
Mean	21	11;3		
SD		0;3		
Range		(10;9-11;7)		
Adults				
Mean	15	17;1		
SD		0;5		
Range		(16;7-18;6)		

Materials. Four different illusions of extent and their controls were graphically displayed on a lap top computer with LCD screen. The stimuli were created using Turbo Pascal 7.0 programming language (see Appendix 3:1 for printout of program). The illusions included the Muller-Lyer, Ponzo, Titchener Circles, and the Horizontal-vertical figures (Hat illusion). They were presented in white on a black background and varied in size from 3x3 cm to 6x11 cm. Examples of the illusions and their controls appear in Figure 3:1.

Figure 3:1

Stimuli for Experiment 3:1



Design. Each illusion task had two conditions of 5 trials. That is, 5 trials were in the illusion configuration and 5 were controls in which the illusory elements were eliminated. These two conditions were alternated and the condition presented first was counterbalanced. Because there were 4 illusions, each participant thus performed 40 trials in total. The presentation order of illusions was fixed as: Ponzo, Muller-Lyer, Titchener Circles, and the Hat illusion.

Procedure. Initially a practice trial was offered to familiarise subjects with the use of the computer keyboard. Instructions were given on which arrow would increase and which would decrease the size of the target object on the screen. A single line and circle were used as examples for the practice trial. Once subjects felt comfortable using the arrows the main part of the experiment began. Each participant was instructed to adjust certain parts of the figure by using the arrow buttons on the keyboard. Each press increased or decreased the size by two pixels. The adjustable parts of the stimuli appeared at random starting points within defined limits. On each trial the experimenter indicated which line or circle needed to be adjusted and which part it needed to match in size. Subjects were instructed to press the "N" button on the keyboard to complete the trial and to begin the next. Subjects were given as much time as necessary to complete all 40 trials. Following each trial the computer automatically recorded the participant's length of line or diameter of circle in number of pixels.

3:4 Results

Raw data fed automatically from the laptop computer into SPSS and ANOVA's were carried out on each of the illusions separately. Condition (2) and trial (5) were included in the analysis as within subjects factors and participant group (5) was entered as a between factor.

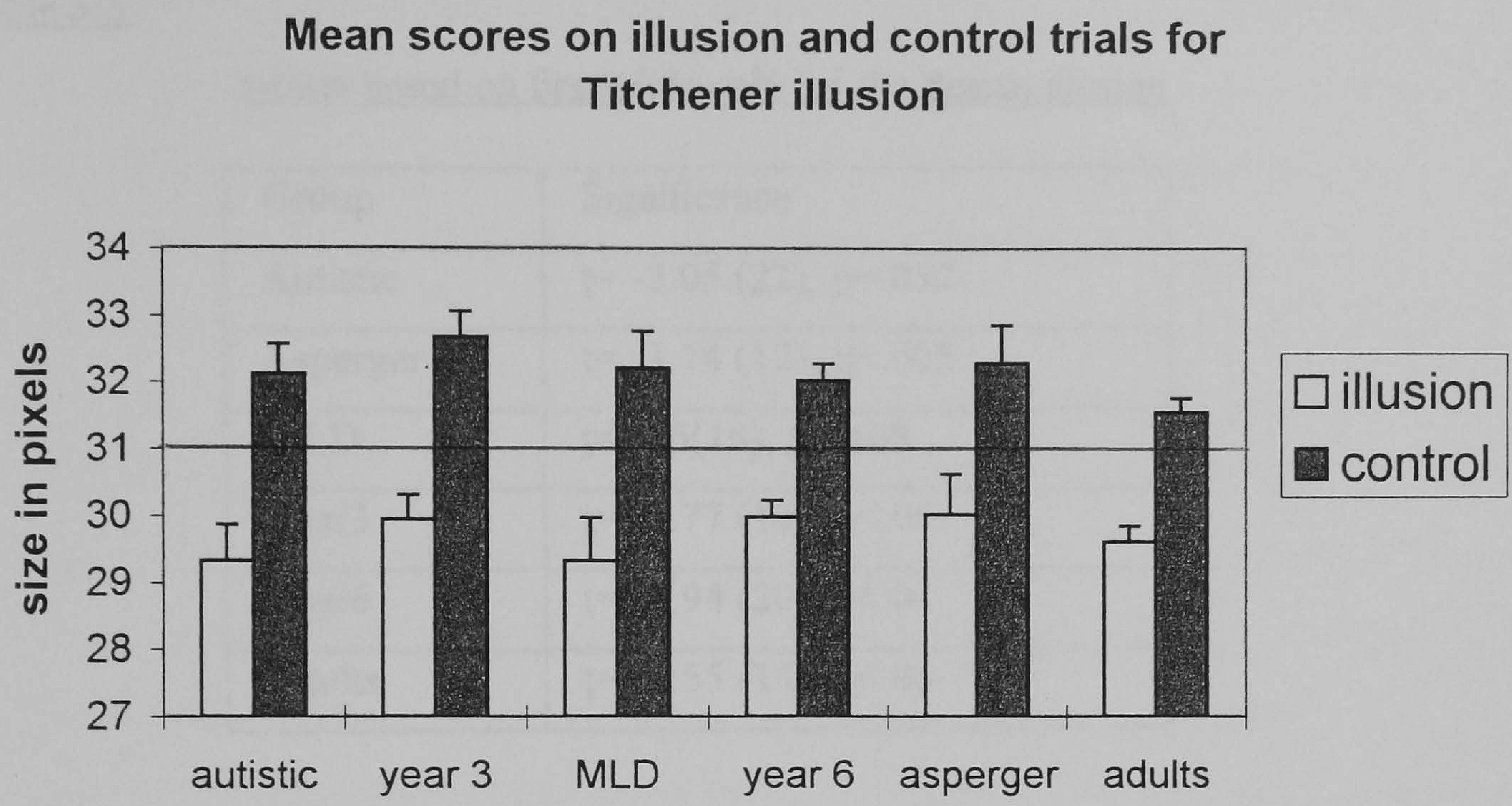
Titchener Circles. Figure 3:2 displays the group means for the illusion and the control condition. The figure shows that all groups scored lower on the illusion than the control, which suggests that the effect of the illusion led to a systematic distortion in perception. The horizontal line indicates the actual number of pixels in size of the circle being estimated. This was apparent as a main effect associated with condition: $F(1,99)=172.87$, $p < .001$. No other effects were significant. It is possible that the distorting effect might become stronger with more exposure to the illusion. This possibility was suggested by Happe through personal communication. Therefore, the first trial on the illusion condition was compared with the first trial on the control condition. The results of the t-tests comparing first trials only for each group are displayed in Table 3:2. All groups significantly underestimated size on the illusion condition suggesting they were susceptible to the illusory effect even on the first trials.

Table 3:2

t-tests based on first trial only for the Titchener illusion

Group	Significance
Autistic	$t= -4.31$ (18), $p<.001$
Asperger	$t= -4.38$ (12), $p<.005$
MLD	$t= -2.63$ (16), $p<.05$
Year3	$t= -5.11$(19), $p<.001$
Year6	$t= -6.83$ (20), $p<.001$
Adults	$t= -4.53$ (14), $p<.001$

Figure 3:2



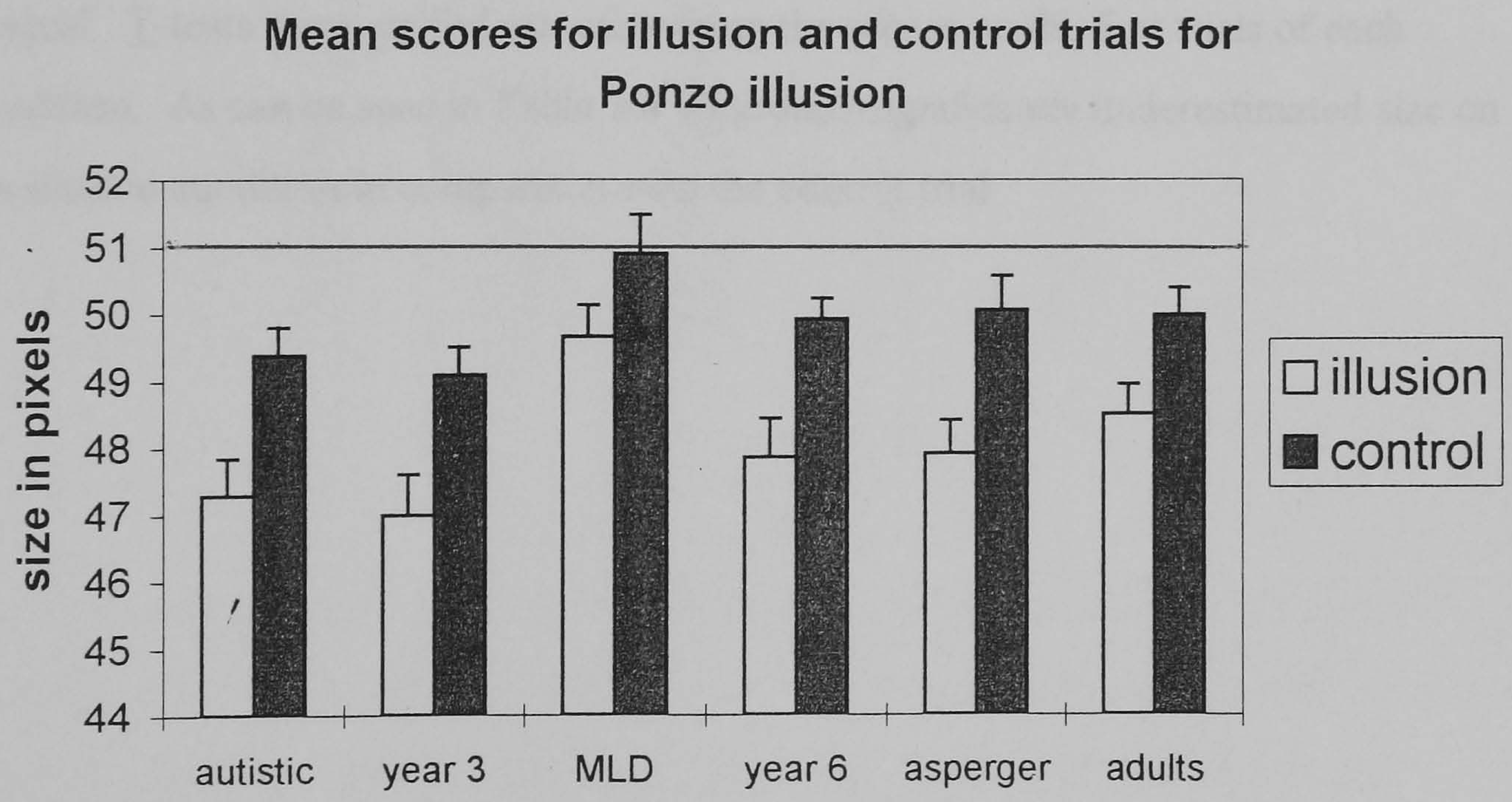
Ponzo. Figure 3.3 displays the group means for the illusion and the control condition. Again, the figure shows that scores were lower in the illusion than the control. The horizontal line indicates the actual size in pixels of the circle being judged. Accordingly, there was a main effect associated with the factor condition [$F(1,103)=77.18$, $p<.001$]. There was also a main effect associated with participant group [$F(5,103)=3.24$, $p< .01$], and a post hoc Tukey analysis revealed that participants in the MLD group generally attained significantly higher scores (combined over trial and condition) than those with autism and the 7-8 year olds. One final weak effect was associated with trial number, and it seems participants tended to generate a larger circle in both conditions with increasing trials: $F(4,412)=2.55$, $p < .05$. No other effects were significant. Again the first trials of each condition were compared using t-tests. The results (see Table 3:3) revealed that neither the autistic or MLD group showed susceptibility to illusions based on first trials only.

Table 3:3

t-tests based on first trials only for the Ponzo illusion

Group	Significance
Autistic	t= -2.05 (22), p=.052
Asperger	t= -3.74 (12), p<.005
MLD	t=-.85(16), p=.408
Year3	t= -2.77 (19), p<.05
Year6	t= -2.94 (20), p<.01
Adults	t= -2.55 (14), p<.05

Figure 3:3



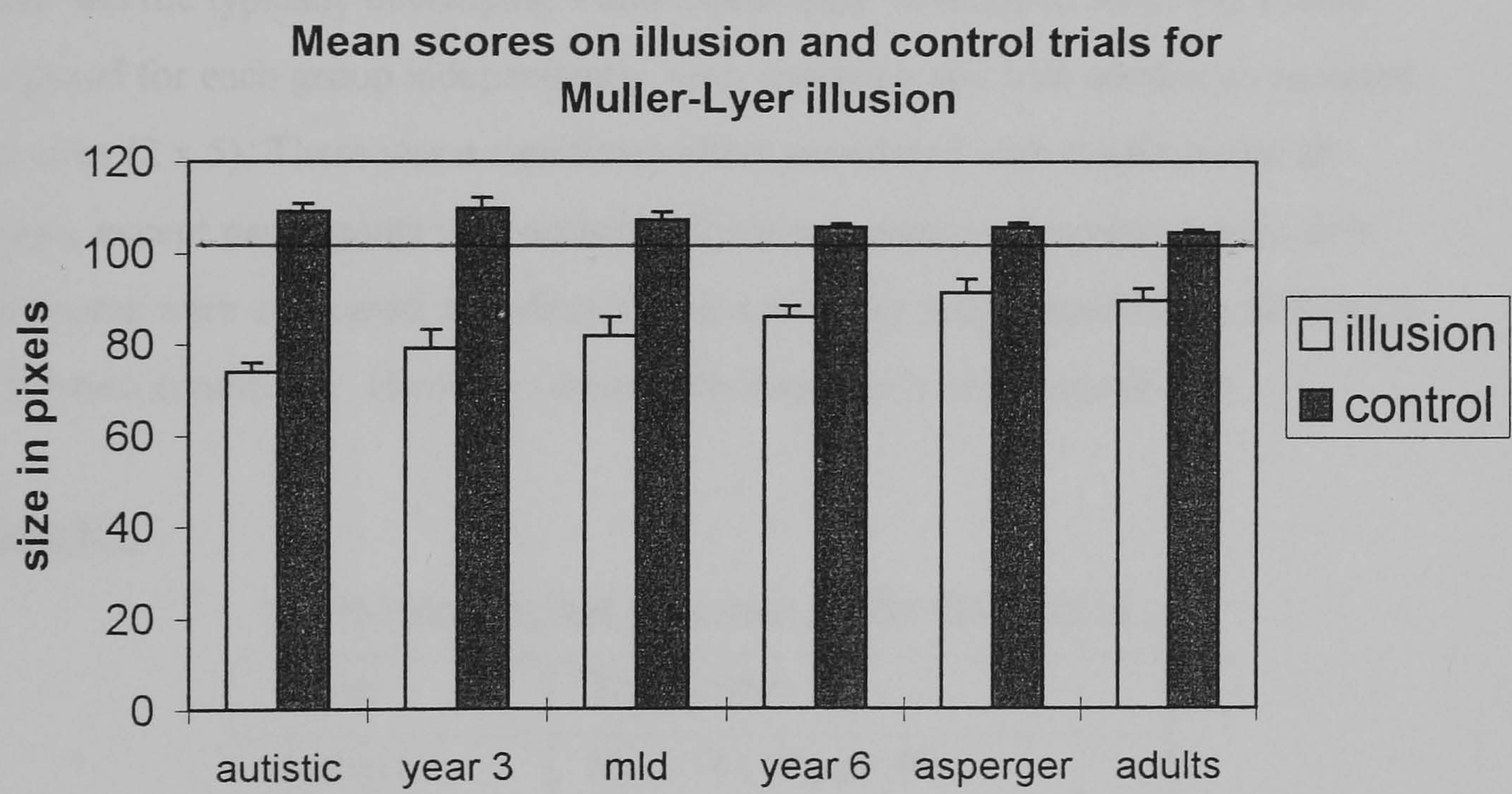
Muller-Lyer. Figure 3:4 suggests that all the participant groups underestimated size in the illusion condition compared with the control: $F(1,102)=262.49$, $p< .001$. The horizontal line on the graph indicates the actual size of the line participants had to judge. As with the Ponzo, there was a weak effect of trial [$F(4,408)= 2.95$, $p < .05$] showing that mean scores increased for all groups as the number of trials progressed. There was no effect associated with group, but group did interact with condition: $F(5,102)=5.95$, $p< .001$. To help decompose the interaction, a between groups analysis for the illusion trials and the control trials was computed independently. There was an effect associated with group for the illusion trials [$F(5,102)=4.17$, $p< .01$] but not for the control trials. A post hoc Tukey test located the effect as pronounced susceptibility to the illusion in the autistic group. They had lower scores than adults, participants with Asperger's syndrome and typically developing children aged around 10 and 11 years. A series of ANOVA's were computed for each group independently, with condition and trial as within factors, which demonstrated that all participant groups underestimated size in the illusion condition compared with the control. T-tests were carried out comparing the scores on the first trials of each condition. As can be seen in Table 3:4 all groups significantly underestimated size on the illusion condition in comparison with the control trial.

Table 3:4

t-tests based on first trials only for the Muller-Lyer illusion

Group	Significance
Autistic	t= -12.62 (21), p<.001
Asperger	t= -3.94 (12), p<.005
MLD	t= -2.12 (16), p=.050
Year3	t= -4.39(19), p<.001
Year6	t= -7.45 (20), p<.001
Adults	t= -4.72 (14), p<.001

Figure 3:4



Perhaps the difference between groups in susceptibility to the illusion reflects a maturity effect. Although the correlation between illusion score and chronological age was non-significant (r(106)=.11), there was a significant correlation with verbal mental age for the clinical groups: r(50)= .36, p= .009. This indicates a decrease with illusion strength as verbal mental age increased.

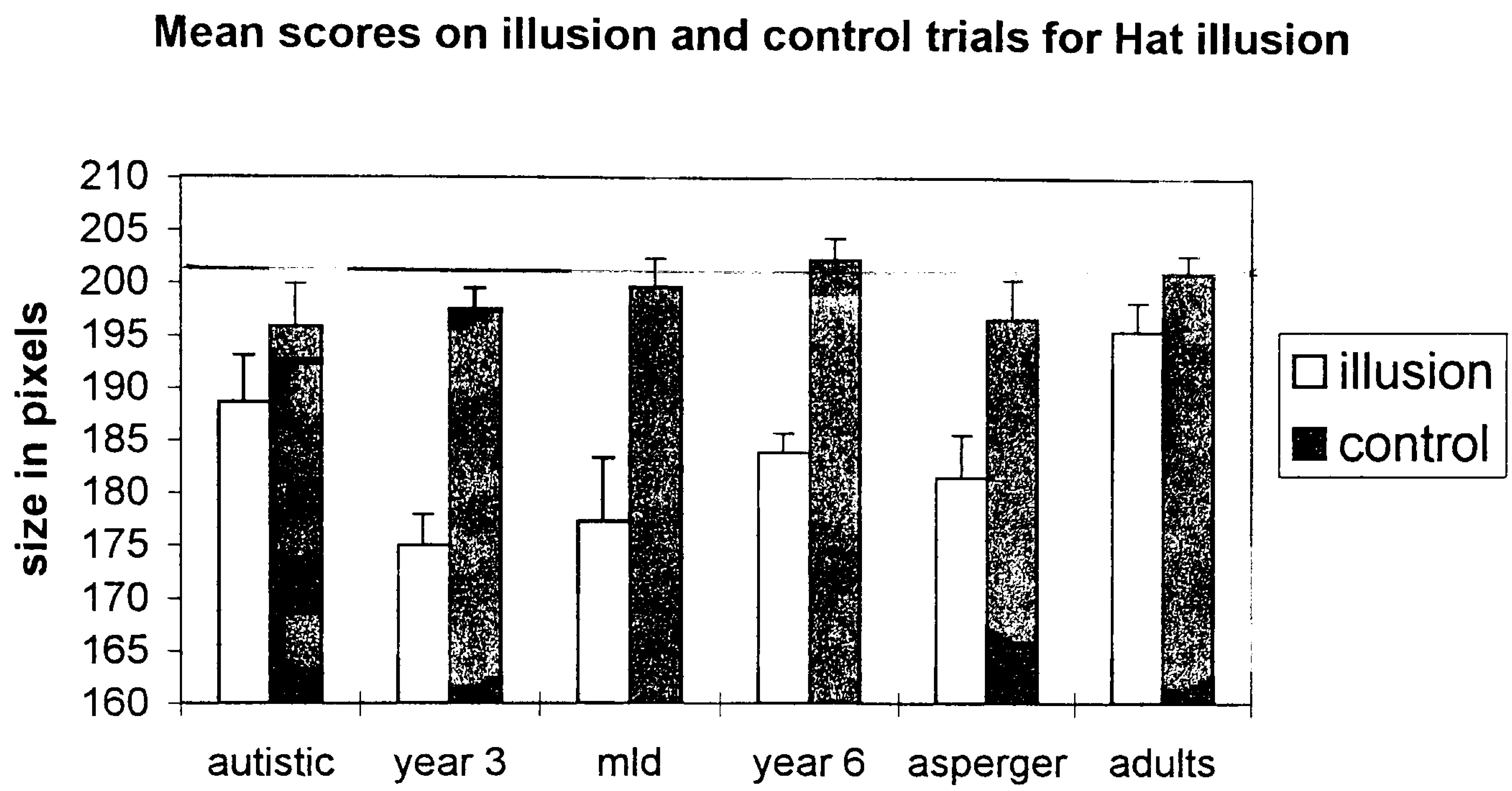
Hat. As with the other illusions, estimates of the target stimulus were lower in the illusion condition than in the control (Figure 3:5). The actual size of the line being judged is shown by the horizontal line on the graph. This was confirmed by a main effect associated with condition [$F(1,98)=83.48$, $p<.001$]. Once again, participants generally gave larger estimates under both conditions with increasing trials: $F(4,392)=9.55$, $p< .001$. There was a main effect associated with participant group [$F(5,98)=2.43$, $p< .05$] and this factor interacted with condition [$F(5,98)=3.35$, $p<.01$]. To help interpret the interaction, ANOVA's were carried out independently on the control and illusion condition. There was a significant between-groups effect only for the illusion condition: $F(5,98)=3.77$, $p<.01$. A Tukey test revealed that adults gained higher and therefore more accurate scores compared with the MLD group and the typically developing 7 and 8-year-olds. A series of ANOVA's were computed for each group independently, with condition and trial number as repeated measures (2 x 5). There was a significant effect associated with condition for all groups, except participants with autism. However, when performance on the first trial scores were compared, individuals with autism did judge significantly differently on the two conditions. However, those with Asperger's syndrome did not.

Table 3:5

t-tests based on first trials only for the Hat illusion

Group	Significance
Autistic	$t= -2.54$ (17), $p<.05$
Asperger	$t= -1.10$ (12), $p=.294$
MLD	$t= -2.28$(16), $p<.05$
Year3	$t= -3.94$(19), $p<.005$
Year6	$t= -4.63$ (20), $p<.001$
Adults	$t= -2.39$ (14), $p<.05$

Figure 3:5



Compound scores. Table 3:6 shows the number and percentage of participants who were susceptible to illusions within each group. Each illusion score was subtracted from its corresponding control score in all 4 illusion tasks. Hence, each participant had a total of 20 difference scores, which were entered into a t-test to compare against a hypothetical mean of zero. In the majority of participants, the difference score was significantly above zero at the 5% probability level. The number of participants thus deemed to be susceptible does not appear to vary greatly between the five groups.

Table 3:6

Number and percentage of participants who showed overall susceptibility to illusions in Experiment 3:1

Group	n	Number susceptible to illusions	Percentage susceptible
Asperger	13	10	77%
autistic	23	17	74%
Year 3 (age 7)	20	18	90%
Year 6 (age 11)	21	20	95%
adults	15	12	80%
MLD	17	11	65%

Note. The text explains the basis for deciding who was and was not susceptible to illusions. Six participants with autism had an incomplete data set owing to the fact that they were presented only two or three of the illusions. All 6 showed susceptibility despite the fact that the analysis was particularly conservative in their case.

3:5 Discussion

The overall findings do not support the claim that individuals with autism or Asperger's syndrome are less susceptible to visual illusions than other groups. With the exception of the Hat illusion, there is little suggestion in our data of a deficit in perceptual coherence at a low level.

In the current study, susceptibility to illusions was measured by asking participants to adjust the length of comparison lines or the diameter of comparison circles. In Happe's (1996) study, participants were asked verbally whether comparison stimuli look the same or different. Although there is no difference between population groups in susceptibility to illusions at the level of manual adjustment, perhaps a difference does exist at the level of verbal response. Aglioti et al. (1995) report a surprising difference in susceptibility to the Titchener Circles in normal participants depending on the kind of response they had to make. When asked to reach to the circle that was larger, their judgment was based on apparent rather than physical size. Paradoxically, however, the adjustment of the participant's grip in anticipation of picking up the circle was consistent with the physical rather than apparent properties of the circle.

In Aglioti et al.'s (1995) study, differences in susceptibility occurred between two kinds of manual response. Although there is no evidence to date to suggest that there are differences in susceptibility between a verbal and manual response, Aglioti et al.'s findings do raise this as a possibility. In particular, it might be that while individuals with autism are susceptible at the manual level, they are not at the verbal level. Previous research suggests that participants without autism would show susceptibility in both kinds of measure. A second experiment was conducted that involved a procedure more similar to Happe's (1996) to assess autistic susceptibility to illusions in a task requiring a verbal response.

A final aspect of the results that deserves comment concerns performance in the control condition. Participants sometimes seemed to deviate systematically from the actual size in these, which was most noticeable in the control for the Titchener illusion. Exactly why participants should exaggerate the size of the stimulus remains unclear. On approximately half the trials, the figure that was to be adjusted began smaller than the comparison stimulus, while on the rest it began larger. Hence, the possibility of a response bias associated with initial size can be eliminated. The exaggeration of size was not confined to judgments of circles, since participants showed no such tendency in the control for the Ponzo. It was not confined to judgments based on stimuli that were arranged horizontally, since the effect was not so apparent in the control for the Muller-Lyer. The phenomenon remains a mystery, but it need not detract from the important finding that participants judged differently between illusion and control conditions.

Experiment 3:2

3:6 Method

Subjects. Twenty nine individuals with autism and 18 with Asperger's syndrome participated in the study. The autistic group consisted of 17 males and 3 females while the Asperger's group included males only. All subjects were diagnosed by experienced clinicians according to standard criteria. Once again their verbal mental ages were assessed using the British Picture Vocabulary Scale. The control groups included 17 individuals with moderate learning difficulties (MLD) who were approximately matched to the mean verbal mental age of the autistic group, and 35 children with typical development whose chronological age approximately matched the mean verbal age of the autistic group. Subject characteristics are shown in Table 3:7. Nine of those in the Asperger's group and 6 in the autistic group had previously participated in the first experiment. None of the controls had participated in Experiment 3:1. There was no sign that the inclusion or exclusion of their data affected the overall pattern of results.

Table 3:7

Subject characteristics for Experiment 3:2.

Group	n	CA(y;m)	VMA(y;m)	BPVS Standardized score (VIQ)
Autism				
Mean	29	12;7	6;7	59.1
SD		3;5	2;9	7.7
Range		(7;10-18;10)	(2;7-14;3)	(40-101)
MLD				
Mean	17	14;5	8;4	62.4
SD		1;1	1;3	7.9
Range		(12;3-15;10)	(6;7-10;10)	(42-77)
Asperger's				
Mean	18	15;5	12;1	87.1
SD		5;4	4;0	9.3
Range		(9;5-29;6)	(6;8-19;6)	(40-126)
Normal				
Mean	35	7;9		
SD		0;3		
Range		(7;1-8;2)		

Materials. The stimuli were 16 (21x15cm) laminated cards of visual illusions and their controls. There were four variations of each of the illusions used in Experiment 3:1. Four of the cards had the illusions printed on them as they are normally presented, in which the target stimuli appeared different but were physically the same. The 12 controls were as follows: Four cards showed the illusory context with comparison stimuli that appeared different and were physically different; four showed physically identical comparison stimuli not in illusory context; the final four showed physically different comparison stimuli not in illusory context. The stimuli were printed in black ink on a white background and varied in size from 3x3 cm to 6x11 cm (see Figure 3:6).

Figure 3:6

Stimuli for Experiment 3:2

Illusion same Control same Illusion different Control different

Procedure. Participants were tested individually at their school in a quiet area. Each was told they would be shown lines and circles which may be the same size or different sizes. The 16 cards were shuffled and presented in random order. The experimenter pointed to the comparison lines or circles on each card and asked "Are these two lines/circles the same size or different sizes? The order of alternatives in the test question was counterbalanced between participants.

3:7 Results and Discussion

Responses for the "control same" and "control different" conditions were compared using McNemar analyses to see if participants were sensitive to physical differences in a non-illusory context. These results indicated an extremely strong contrast between conditions for all groups, in that participants usually judged "different" only when appropriate. Despite that, several participants made one or more errors on the 12 control trials: 4 with MLD, 3 with Asperger's syndrome, 10 with autism, and 12 with typical development. Either these participants did not have a clear concept of same-different or they did not always inspect the stimuli adequately.

The percentage of subjects who fell for each illusion appears in Table 3:8. The table includes participants with and without errors on any of the controls. In order to assess whether groups of individuals were susceptible to the illusions, responses between the "illusion same" and "control same" conditions were compared. The results appear in Table 3:9 which shows that participants in all groups were significantly more likely to say "different" on the "illusion same" than "control same" conditions for all illusions except the Hat.

Table 3:8

Percentage of subjects who succumbed to each illusion in Experiment 3:2

Group	Muller-Lyer		Titchener		Ponzo		Hat	
Errors	none	included	none	included	none	included	none	included
Autism	95.0	89.7	75.0	82.8	25.0	37.9	15.0	24.1
MLD	100.0	100.0	84.6	76.5	30.8	41.2	23.1	17.6
Asperger	80.0	77.8	60.0	66.7	46.7	38.9	20.0	16.7
Normal	100.0	97.1	56.5	62.9	34.8	45.7	26.1	22.9

Note. The term "none" refers to participants who did not make errors in control conditions and the term "included" refers to all participants, including those who made control errors.

Another series of McNemar comparisons was carried out between the "illusion same" and the "illusion different" conditions, to address the question: Are participants more sensitive to a physical than illusory difference between stimuli? In all four groups, participants were more likely to judge a difference between stimuli when that was physical rather than illusory for the Ponzo and Hat illusions. The same was also apparent in the Titchener illusion for those with Asperger's syndrome and those with typical development. Although this set of results suggests that participants were sometimes more sensitive to differences between stimuli when they were physical, once again there is no suggestion that the individuals with autism were peculiarly resistant to illusory effects. Indeed, a series of χ^2 tests failed to detect any differences between groups in terms of susceptibility to any of the illusions irrespective of whether those who failed controls were included or excluded. To generate an even more sensitive between-groups test, the number of illusions that each participant fell for was calculated, minus the number of errors in the "control same" condition. A one-way ANOVA between groups was carried out but once again the comparison was nonsignificant: $F(3,95)=1.01$, n.s.

Table 3:9

Results from the Mc Nemar analysis showing responses for illusion same and control same conditions all at 1 degree of freedom (Experiment 3:2)

Group	Muller-Lyer	Titchener	Ponzo	Hat
Autism	*23-1, $p<.001$	20-1, $p<.001$	8-0, $p<.02$	5-5, n.s.
MLD	17-0, $p<.001$	12-0, $p<.01$	6-0, $p<.05$	3-1, n.s.
Asperger	13-0, $p<.001$	11-0, $p<.01$	7-0, $p<.05$	3-1, n.s.
Normal	30-1, $p<.001$	22-1, $p<.001$	13-3, $p<.05$	6-2, n.s.

* Twenty three participants judged "different" in the illusion trial and "same" in the control trial. Only 1 participant judged "same" in the illusion trial and "different" in the control trial.

3:8 General Discussion of Experiments 3:1 and 3:2

In experiment 3:1, participants adjusted lines or circles to match a target in a context that was expected to provoke an illusory distortion. In general, participants with autism and Asperger's syndrome were demonstrably susceptible to the illusions by virtue of their systematic underestimation of the target stimulus specifically in the illusion condition. This underestimation is explained by the illusory context. Moreover, the effect of the illusion usually appeared to be as strong in those with autism as those without. Participants also showed susceptibility when making verbal judgments about the properties of lines and circles in illusory contexts. There is one exception, which is that participants with autism did not show susceptibility on the Hat illusion relative to the control condition.

Generally, these results are not consistent with Happe's (1996) finding that individuals with autism are somewhat immune to visual illusions. It might have been that the difference between those with and without autism was detectable only at the level of verbal response, but the results of Experiment 3:2 do not support such a possibility. Perhaps the verbally-based response required in Happe's study somehow led participants with autism to answer "same" in the illusion condition. Although participants were required to respond verbally in Experiment 3:2, the procedure differed from Happe's in some aspects of detail such that participants were not led to answer "same". An alternative though perhaps less likely possibility is that Happe's autistic participants had already been acquainted with visual illusions and responded in accordance with what they knew rather than what they could see.

If individuals with autism are susceptible to visual illusions, as our results suggest, then there are no grounds for supposing that coherence is weak at low levels of perception. When an individual with autism looks at a stimulus, like Titchener Circles, it seems their assessment of the inner target circle will inevitably be affected by the presence of the outer circles. Apparently, our perceptual systems are wired to analyse the target in its visual context, and that applies to people with or without autism. It does not necessarily mean, however, that individuals with autism would be influenced by visual context at all levels of processing. For example, they might be effective in ignoring the identity of an object as suggested by its global shape when searching for constituent objects hidden therein, which is required in an embedded figures test.

Also, Jarrold and Russell (1997) report that individuals with autism gain less advantage in terms of speed of counting when dots are presented in canonical form (as in the face of a dice), than when presented in ad hoc form. In canonical form, it seems participants without autism subitized, while those with autism attended to dots individually. Hence, they showed local over global preference on this level of visual attention. A somewhat different line of evidence also indicates impairment in global processing in autism. Hobson, Ouston and Lee (1988) report that individuals with autism show an advantage over control participants in matching faces when presented upside-down. Perhaps participants without autism are particularly hampered when processing inverted faces if their global approach to processing is based specifically on the canonical orientation of the face. Inverting a face would not be an impediment to those with autism if their processing was directed more at the local detail of the stimulus.

In these various tasks, suppression of the global Gestalt might require a deliberate act of will. We do not know whether they have a preference and indeed an aptitude for focusing on detail whilst ignoring the whole or whether the whole does not impress itself upon them so strongly. An illusion is quite different. Importantly, it is not apparent to a naive individual that an act of will is needed to give a correct judgment. Rather, participants succumb to the illusion without realising they have done so. A capacity for single mindedness in deliberate acts of attentional focus would be no use in a task where one succumbs to perceptual distortion unwittingly.

The preceding discussion highlights the kind of difficulty that is likely to be encountered when contemplating a rather vague concept like "weak central coherence". Although the concept has intuitive appeal, it is hard to define the terms "central" and "coherence". The autistic intellectual profile is characterised by more severe deficits in verbal than non-verbal intelligence. Presumably, however, the term "weak central coherence" should mean something more specific than this. Perhaps it would be fair to say that a typical cognitive style of individuals with autism leads them to process information locally. Even so, we would still need to ask when this style of processing is evident. Apparently, it does not occur at the level at which visual illusions work. In consequence, it is difficult to make predictions of autistic performance on novel tasks. Perhaps weak central coherence can only be postulated once we have established a peculiarity in autistic performance in a given domain.

Previous findings have not always given support to the possibility of weak central coherence in autism. Brian and Bryson (1996) devised a particularly elegant embedded figures procedure in which the level of abstractness of the global shape varied between stimuli. If participants with autism were not distracted by the global shape, then not only would they find the embedded figure faster than controls, but the level of abstractness of the global shape would make no difference to their performance. Unexpectedly, participants with autism were no faster than controls and their disembedding was slower when the global shape was meaningful rather than abstract. However, Jolliffe and Baron-Cohen (1997) noted several factors that could have accounted for Brian and Bryson's failure to find a superiority effect, such as the inclusion of participants with pervasive developmental disorder within the autistic sample and the use of conservative statistical tests.

A recent study by Mottron, Burack, Stauder and Robaey (1999) also fails to support the weak central coherence hypothesis in a sample of high-functioning adults with autism. Participants performed a mental synthesis task, in which they were required to judge whether part-figures shared similarity with a larger figure. Some figures were deemed to be "good", by virtue of the fact that they formed an enclosure without redundant appendage lines (e.g. a triangle), while others were deemed "bad" if they did not possess such properties. From the hypothesis of weak central coherence, the authors predicted that individuals with autism would generally have faster response times than controls. Also, unlike controls, they should have no advantage with "good" over "bad" figures. Neither hypothesis was supported by the data.

Even so, it remains a possibility that symptoms of weak central coherence can be found, but only in a subset of individuals with autism. In that case, the utility of the concept would be undermined because these symptoms would not count as a defining feature. At best, it would appear that autism presents a risk of measurable weak central coherence. The concept would be more useful if we had a range of converging measures that identified specific individuals. It might be that the individuals with autism who show especially good performance on embedded figures are the same who speedily solve block design problems and who are prone to ignore context in their pronunciation of homographs. It might even be that these individuals in particular are less susceptible to visual illusions than others with autism and those with typical development.

The rather sparse extant data are not promising with respect to the prospect of finding resistance to visual illusions in those who show signs of weak central coherence across a range of tasks. Mottron and Belleville (1993) report that E.C. was distinguished by his preference for local rather than global processing in Navon's (1977) task. He was asked to state the letter element in a larger shape that actually formed a discrepant letter. For example, small S's combined to form a large H. Unlike control participants, E.C. was not hampered by the discrepant letter that was formed by the global shape. Hence, E.C. apparently preferred to process locally rather than globally, and by virtue of that he was a prime candidate for showing symptoms of weak central coherence. As already mentioned, though, he was just as susceptible to visual illusions as control participants.

CHAPTER FOUR

Measures of WCC: Is susceptibility to illusions related to performance on visuo-spatial tasks?

4:1 Variation in coherence ability

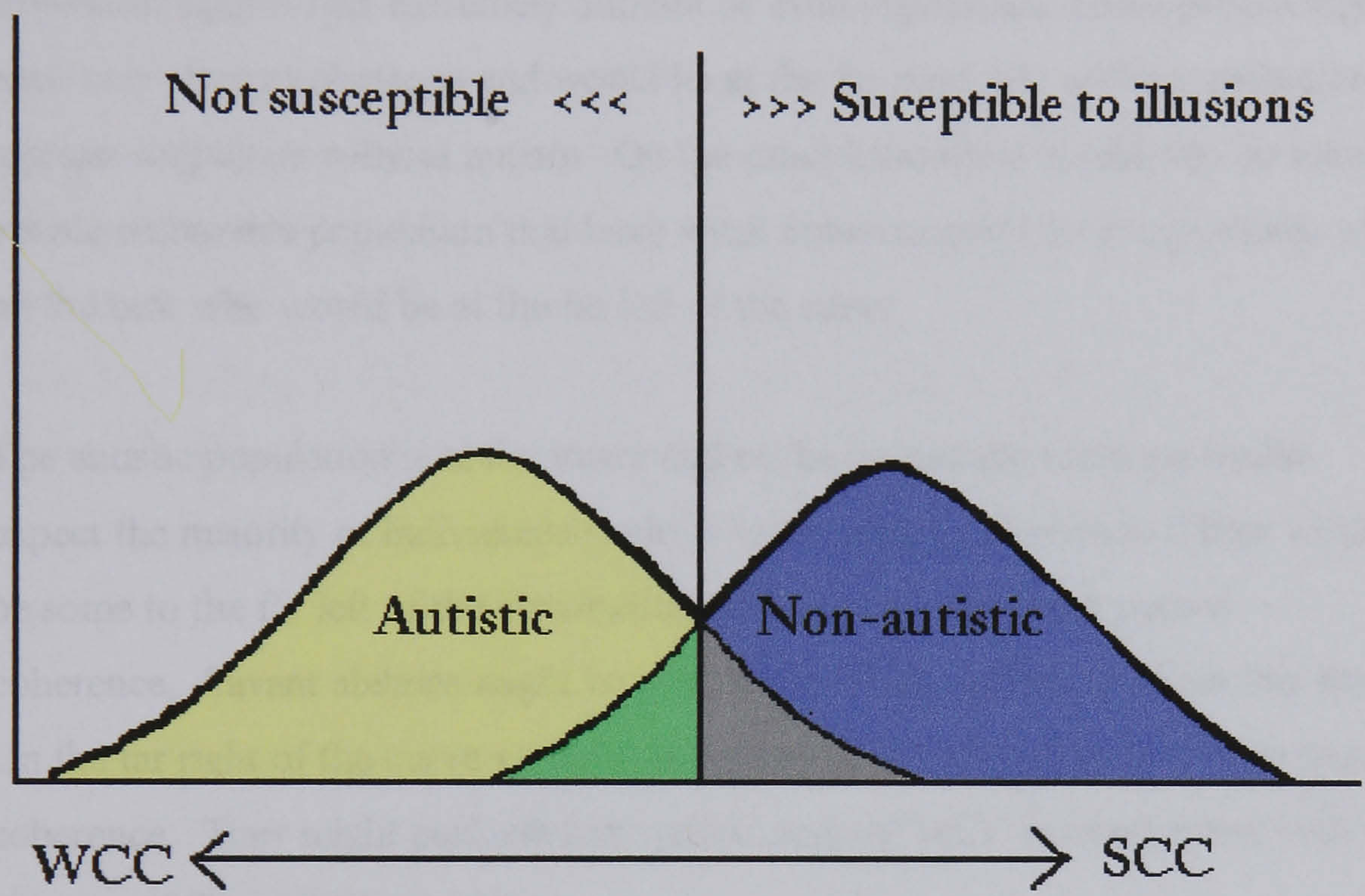
Happe (1999) has suggested three levels at which we might find deficits of coherence in autism: perceptual, visuo-spatial-constructional, verbal-semantic. She suggests that visual illusions require coherence at a perceptual level. An individual would simply need to integrate the lines and shapes together in order to succumb to the illusion. In everyday life we need to integrate basic elements in order to perceive objects, pictures, and people. For this reason we might not expect individuals to have a problem with coherence at this level. However, clinical reports have mentioned occasions where fragmented perception has been noted by autistic individuals. Happe argues that tasks such as the embedded figures and block design may involve visuo-spatial-constructional coherence. With these tests there are many more aspects to integrate which place demands on information processing. The information an individual is required to visually segment or integrate on visual spatial tasks may be meaningful (e.g. embedded figures) or non-meaningful (e.g. block design). Finally, she suggests that tasks involving language comprehension would tap coherence at higher levels. This involves extracting information from individual components (e.g. words) in order to create a meaningful whole (e.g. sentence or story). While problems with language are quite pervasive in autism, the extent to which perceptual deficits persist is still in need of further investigation. Therefore, I have decided to restrict the current investigation to WCC tests at the first and second levels which are of a more perceptual nature.

In the previous study I investigated whether WCC may be evident in autism at low levels such as in the perception of visual illusions. I found that individuals with autism were just as susceptible as those without autism indicating on a group basis that coherence was not weak at this level. These findings are inconsistent with those reported by Happe (1996). There are several ways these conflicting results might be interpreted. It could simply be that individuals with autism do not have coherence deficits at very low levels. Happe herself commented that her findings were surprising in suggesting otherwise. It could also be that illusions do not measure WCC, and Happe's results were due to an artefact.

There may be an alternative explanation that does not counter Happe's theory. It could be that illusions do measure WCC, but there may be subgroups within the autistic population that differ by degree of coherence ability. Most research has primarily considered "weak central coherence" as something a person either has or does not have. For instance, tests such as the embedded figures or block design have usually equated good performance with "weak coherence". This assumption neglects an important point made by Happe (1994a, page 125) who argues that central coherence is a cognitive style that varies in the normal as well as the autistic population. Therefore, it makes more sense for us to consider the extent to which an individual displays weak central coherence, rather than whether they have it or do not have it. Coherence ability then varies within populations as well as between populations. Thinking of coherence in these terms carries several implications. If both populations with and without autism vary in degree of coherence ability then we might expect them to overlap. Figure 4.1 may help to illustrate this point.

Figure 4:1

Variation in coherence ability



The 'x' axis indicates the level of coherence ability in the general population which ranges from very weak to very strong. Those with autism might be expected to lie more towards the left end of the continuum since WCC is characteristic in this population. Those without autism who are less likely to show WCC would be more towards the right of the scale. However, within each of these populations there will be variation in coherence ability. This is represented by a normal distribution for each population.

In those without autism it is likely there may be a few who have relatively weak or strong coherence. An individual with average coherence would be someone who may be inclined to process information globally, however they would also be capable of processing local information when needed to. Thus, although global information may take priority, they would be able to alternate between using both strategies. Since they are able to use both global and local processing styles, they are likely to experience some interference problems. For instance, on the embedded figures task an individual's search for the hidden figure is slowed as a result of resisting the global larger figure. It is important to note that their performance is slowed; it is not impossible for them to break the design down into its component parts. However, it is likely that some individuals would find the embedded figures task extremely difficult or even impossible. These people may have very strong coherence and would lie at the far right side of the distribution representing those without autism. On the other hand there would also be some people within this population that have weak coherence and do exceptionally well on the task who would be at the far left of the curve.

The autistic population is at the lower end of the continuum since we would expect the majority of individuals to show weak central coherence. There would be some to the far left of the distribution having extremely weak central coherence. Savant abilities might be typical of individuals falling within this area. On the far right of the curve would some individuals with autism having stronger coherence. They might perform less well on tests of WCC in comparison with the average of the autistic population.

It is possible that individuals at the lower end of the distribution representing those without autism may perform similarly to those at the higher end of the autistic population. These individuals may fall in the shaded grey and green areas of the figure which shows how the two groups would overlap. The vertical line on the graph could indicate the point at which individuals either are susceptible or are not susceptible to illusions. Thus, everyone falling to the left of the line would not succumb to illusions, and everyone to the right of the line would. It could be that the individuals with autism from our study that were susceptible to illusions primarily fell to the right side of this shaded area (grey area). The shaded green area to the left side of the vertical line would then represent those with autism and typical development who were not susceptible to illusions.

Evidence to support this explanation can be found in a study by Pring, Hermelin and Heavey (1995). The aim of their study was to see whether WCC may be a characteristic of those with artistic ability as well as those with autism. They tested both artistically talented as well as non-talented individuals with normal development and autism. They compared all four groups to look at how autism (diagnosis) and artistic ability were related with performance. Participants were presented with a picture puzzle task and the block design test. Both tasks can be argued to test WCC as it requires an individual to visually segment a design or picture in order to recreate it using individual blocks. Therefore, a global processing style would actually hinder one's ability to perform well. The picture puzzle task depicts a meaningful scene rather than an abstract design like the block design test.

In the block design task the two artistic groups performed at the same superior level while the non-gifted autistic group did significantly better than the non-talented individuals with typical development. On the picture puzzle task however the pattern of results was in the opposite direction. The two non-talented groups performed at the same level, while the talented control subjects did better than savants. They concluded that artistic ability as well as autism enhanced performance independently of each other.

The importance of this study is that it provides an example of how coherence ability varies in both autistic and non-autistic populations. It also shows how individuals without autism may perform similarly to those with autism on a test of coherence such as the block design task. Even though the non-autistic participants that performed particularly well on the block design were artistically talented, it cannot be assumed that having WCC would be sufficient for artistic ability to arise. Likewise, WCC may be characteristic of those with autism, but it does not mean all those with this cognitive style will be autistic. It could however be inferred from this study that having a cognitive style such as WCC may be more common in those with autism or artistic ability.

Although exceptional performance on tasks associated with WCC is more common in the autistic population, it is not universal. For example, Brian and

Bryson (1996) did not find individuals with autism to be any better at the embedded figures task than comparison groups. This conflicts with findings from other studies where a superiority effect in the autistic group was demonstrated (Shah & Frith, 1983; Jolliffe & Baron-Cohen, 1997). Jolliffe and Baron-Cohen (1997) offered several explanations for these conflicting findings. One suggestion was that there might be subgroups in the autistic population as revealed by the searching styles of individuals on the embedded figures test. In Brian and Bryson's (1996) study only one individual with autism showed an immediate search strategy. However, both Shah and Frith (1983) and Jolliffe and Baron-Cohen (1997) reported that a number of individuals with autism found the hidden shape immediately. Therefore, it might be that the autistic population in Brian and Bryson's study consisted of individuals in the shaded grey area of our diagram Figure 4:1, having stronger coherence.

Altogether, the studies above provide examples of how coherence ability can vary in autism and in those with typical development. Pring et al.'s (1995) study demonstrates how two groups in the autistic population (savant artists and non-savants) may differ in performance. Both were superior to non-artist controls, however the savant artists were still significantly better than non-savant autistic individuals.

It seems reasonable then to ask whether subgroups in coherence ability might explain our failure to replicate Happe's results. Our study may have encapsulated a sample of individuals that would not do well on the block design test and the embedded figures test, while those individuals in Happe's study may have excelled at these tasks. The following section explains how I intend to investigate this matter.

4:2 Introduction

The primary aim of this study is to explore individual differences in coherence ability in autism. I predict that those individuals who score highest on measures of WCC within the autistic group would be least susceptible to illusions. The embedded figures and the block design have generally been accepted as measures of coherence ability and since some research has found correlations between these two tests (Jarrold et al., 1999) it seems appropriate to use these as part of our investigation. In addition to these more traditional tests of WCC the Rey complex figure test was also administered (Rey, 1959). This test is used to investigate perceptual organisational and visual memory abilities. There are several reasons for including this as part of the battery of tasks.

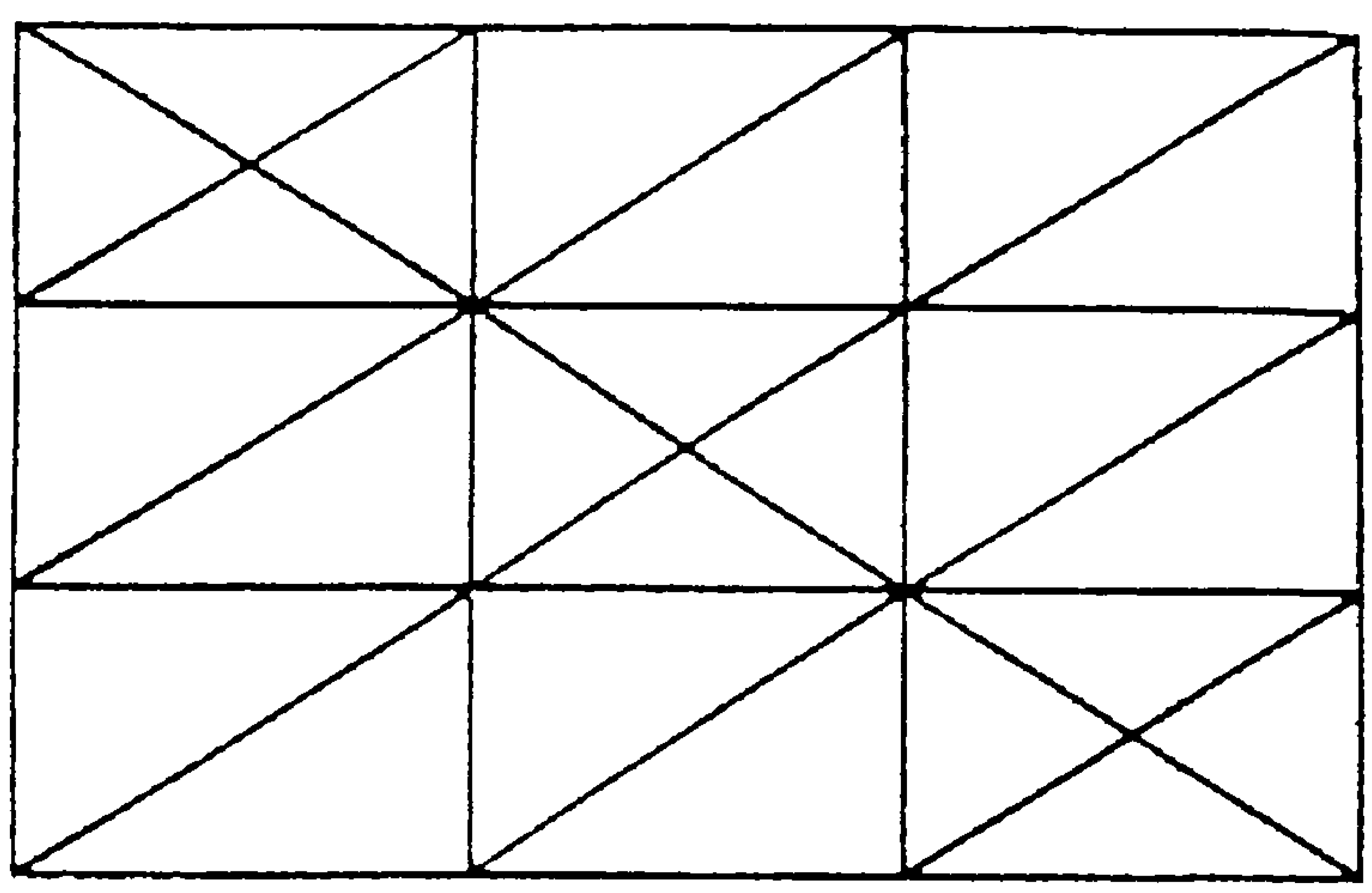
In Pring, Hermelin, and Heavey's study (1995) it was shown that individuals with artistic ability (autistic and non-autistic) did exceptionally well on the block design, suggesting they had weak central coherence. Therefore, it is expected that those who do well on the embedded figures, and block design, might also demonstrate good drawing ability on the Rey figure test. This test can give us an estimate of a person's drawing ability. It requires an individual to copy a figure once with the stimuli in view which is referred to as the copy trial. The person is then asked to draw the figure again 3 minutes later from memory in the recall trial. A person is awarded points for accuracy and placement for each part of the overall design. This test can also tell us about an individual's drawing style.

When asked to copy the Rey figure an individual might begin by drawing the outline. This would indicate he or she was using a global strategy. Alternatively, a person might use a local strategy which would entail focusing more on the details of the figure when drawing. According to the theory of WCC we would expect those with autism to show a preference to use a local strategy, while those with typical development might use a global strategy.

Previous studies that have presented the Rey figure test to individuals with autism have found that they do indeed show a preference to use a local strategy. A case study carried out on a mathematical savant included the Rey figure as part of their battery of tests (Steel, Gorman, & Flexman, 1984). They reported that he focused primarily on internal elements rather than the global outline. They also noted that he had considerable difficulty with recall from memory. Prior and Hoffman (1990) presented the same test to a group of 12 individuals with autism (non-savants). They observed that autistic children showed an odd and disorganised drawing style. Participants focused primarily on the details rather than the outline of the figure, unlike controls. Although the autistic group performed similarly to controls on the copy trial, performance on the recall trial was poor in comparison. The sample size of both these studies was quite small. Therefore, more research in this area is needed to establish whether or not this finding can be replicated. Furthermore, a recent study by Jolliffe and Baron-Cohen (1997) did not find a preference to draw details first in individuals with autism. However, they argued their failure to replicate past findings may be due to their using an adapted version of the Rey figure test (see Figure 4:2). This simplified version was used in order to make it easier to determine whether an individual was drawing the global outline or details of the figure. However, they found that the autistic group was just as likely as the non-autistic groups to begin drawing with the global outline. They suggest that the figure may have been oversimplified to the extent that a bias to draw details first could not be detected.

Figure 4:2

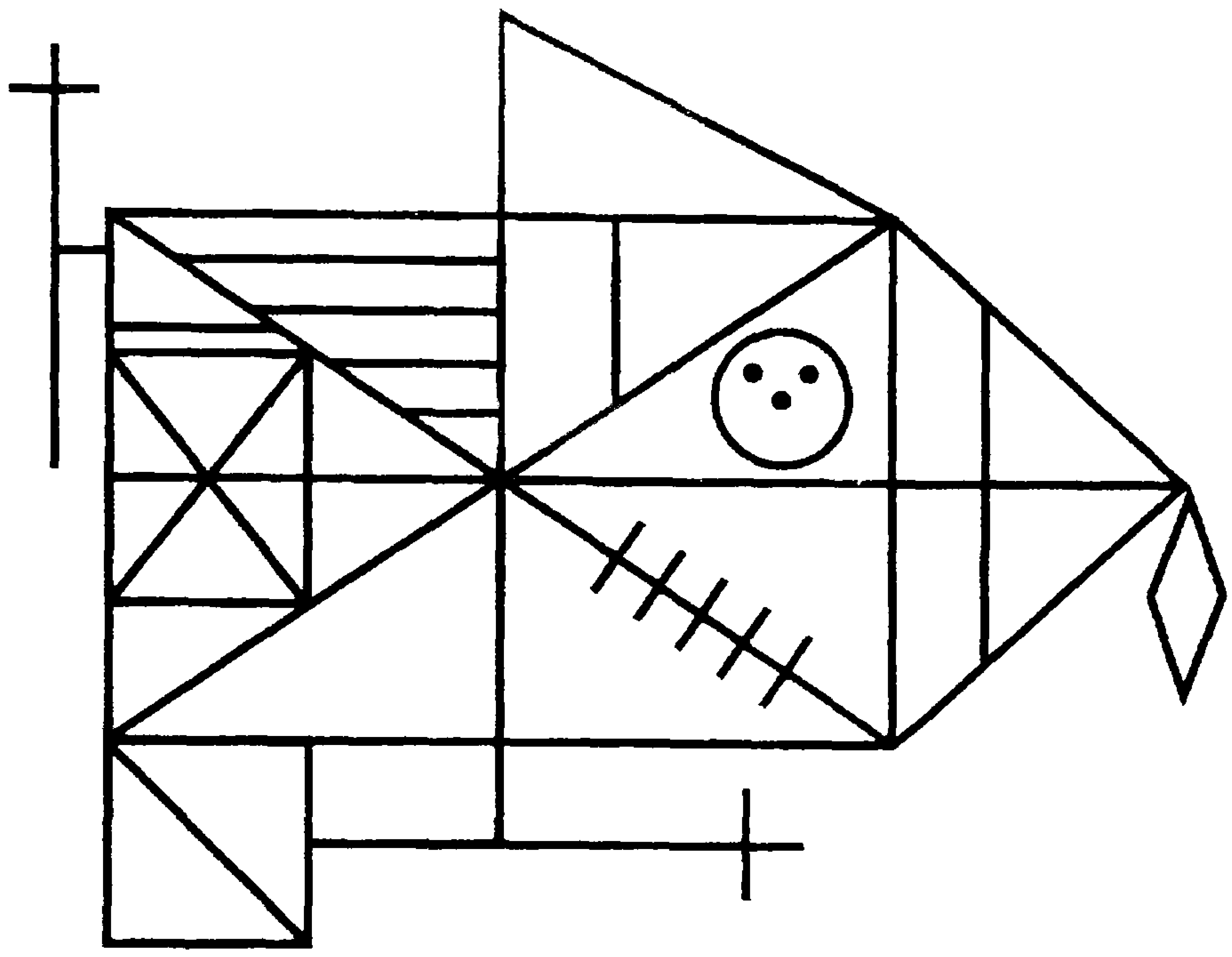
Simplified Rey figure



Although the original Rey figure may make coding for local or global drawing strategies complicated, it seems more likely to reveal differences in drawing style. Therefore, the original Rey figure stimulus was used in the current study (see Figure 4:3). One would expect that those who perform well on the Rey copy trial and who show a local drawing strategy would be the same who perform well on the embedded figures test and the block design task. These measures should correlate with one another if they are all related to coherence ability. Furthermore, it would be expected that individuals with autism would be more likely than controls to perform well on this battery of coherence tasks. However, based on previous findings, poor performance on the recall trial in the autistic group would anticipate would be expected.

Figure 4:3

Rey complex figure



There is also a newer part of the Rey figure test called the recognition trial which to my knowledge has not been administered to individuals with autism before. The recognition trial awards points for correctly recalling or rejecting component parts of the Rey figure. Twenty-two of these items are smaller components of the Rey figure, while only 2 of the designs are similar to the global shape of the figure. The participant needs to identify only the correct items and reject the distracters.

The Rey figure test then provides several ways to investigate coherence ability. One would expect that those who attend more to the global outline when drawing the Rey figure, might be worse in recalling the local designs. Those who use a local drawing strategy may spend more time processing the details. Therefore, they might be better at recognising the local designs.

Altogether the embedded figure test, block design, and Rey figure task (copy, recall, and recognition trials) make up a battery of tasks which can give us a good indication of a person's coherence level. If they do test the same ability (i.e. coherence), all these measures should correlate with one another. Administering these tasks will provide a profile of each individual's abilities, and also allows us to look at group patterns of performance. Performance on these tasks can then be examined to see if it can predict susceptibility to illusions. In order to measure susceptibility to illusions we employed the same computer task as in our prior study. This would allow a very specific measure of illusion susceptibility to determine whether those who were most strongly susceptible excelled on the battery of tests (embedded figures, block design, Rey figure).

Thus, our general hypotheses for this study are: (1) Performance on all four kinds of task should correlate if they are all indeed tapping coherence ability. (2) Specifically, performance on tasks associated with WCC should be associated with susceptibility to illusions. (3) Those on the autistic continuum would be expected to perform better than controls on the battery of WCC tasks.

Method

4:3 Subjects

Nineteen individuals with autism participated in this study. They had all been diagnosed by experienced clinicians. Only 2 failed to complete all the tests. They were unable to finish the embedded figures test due to frustration with the task or being distracted by the stylus. The British Picture Vocabulary Scale (BPVS; Dunn, Dunn, Whetton & Pintilie, 1982) was carried out on both clinical and control participants to establish verbal mental ability (VMA). The autistic group had a mean chronological age (CA) of 14;2 and mean verbal mental age (VMA) of 11;6. Further details are provided in Table 4:1. A group of 11 individuals with Asperger's syndrome were also included in the study (with an average CA of 11;10 and VMA of 9;11). This allowed us to investigate whether there were any differences between the two autistic subgroups in their perceptual ability. There were three groups of control subjects including children with normal development in year 3, year 6, and individuals with moderate learning difficulties (MLD). The autistic group was exactly matched with the MLD group for VMA. The autistic and MLD groups were also closely matched according to sex in case of any sex differences. Details on sex are given for this particular study because previous literature suggests that males have better visuo-spatial ability than females (Baron-Cohen & Hammer, 1997b).

Table 4:1

Subject characteristics for Experiment 4:1

Group	CA (y;m)	VMA(y;m)	Sex (males; females)
Autistic (N=19)			
Mean	14;2	6;11	17; 2
SD	2;5	2;1	
Range	9;3-18;3	3;8-13;4	
Asperger's (N=11)			
Mean	11;10	9;11	9; 2
SD	2;0	4;0	
Range	(8;4 –15;4)	(5;1-17;6)	
MLD (N=20)			
Mean	12;11	6;11	17; 3
SD	1;5	1;9	
Range	9;2-14;8	3;3-10;10	
Year 3 (N=19)			
Mean	8;6	8;0	9;10
SD	0;4	1;7	
Range	(7;7-8;6)	(5;3-10;6)	
Year 6 (N=18)			
Mean	11;3	11;6	10; 8
SD	0;4	2;0	
Range	10;9-11;7	9;5-15;7	

4:4 Visual illusion computer task

Materials. The same four illusions used in Experiment 3.1 were graphically displayed on a lap top computer with LCD screen. The Muller-Lyer, Ponzo, Titchener, and Hat stimuli were created using Turbo Pascal 7.0 programming language. They were presented in white on a black background and varied in size from 3x3 cm to 6x11 cm.

Design. A few modifications were made to the original computer program. Firstly, the number of trials was changed to 6 per illusion reducing the total number of trials from 40 to 24. This allowed for a shorter testing time which would hopefully decrease the chance of individuals becoming bored and not finishing the task. Once again, half of the trials were in the illusion condition and the remaining were controls in which the illusory elements were eliminated. These two conditions were alternated and the condition presented first was counterbalanced. The presentation order of illusions was always the same: Ponzo, Muller-Lyer, Titchener Circles, and the Hat illusion. Another difference was that the Ponzo illusion was reversed. Therefore, susceptibility would result in overestimation rather than underestimation on the illusion condition. This was due to an oversight, but there was no reason to expect it would affect the results.

Procedure. Initially a practice trial was offered to familiarise subjects with the use of the computer keyboard. Instructions were given on which arrow would increase and which would decrease the size of the target object on the screen. A single line and circle were used as examples for the practice trial. Once subjects felt comfortable using the arrows the main part of the experiment began. Each participant was instructed to adjust certain parts of the figure by using the arrow buttons on the keyboard. Each press increased or decreased the size by two pixels. The adjustable parts of the stimuli appeared at random starting points within defined limits. On each trial the experimenter indicated which line or circle needed to be adjusted and the part it needed to match in size. Subjects were instructed to press the "N" button on the keyboard to complete the trial and to begin the next.

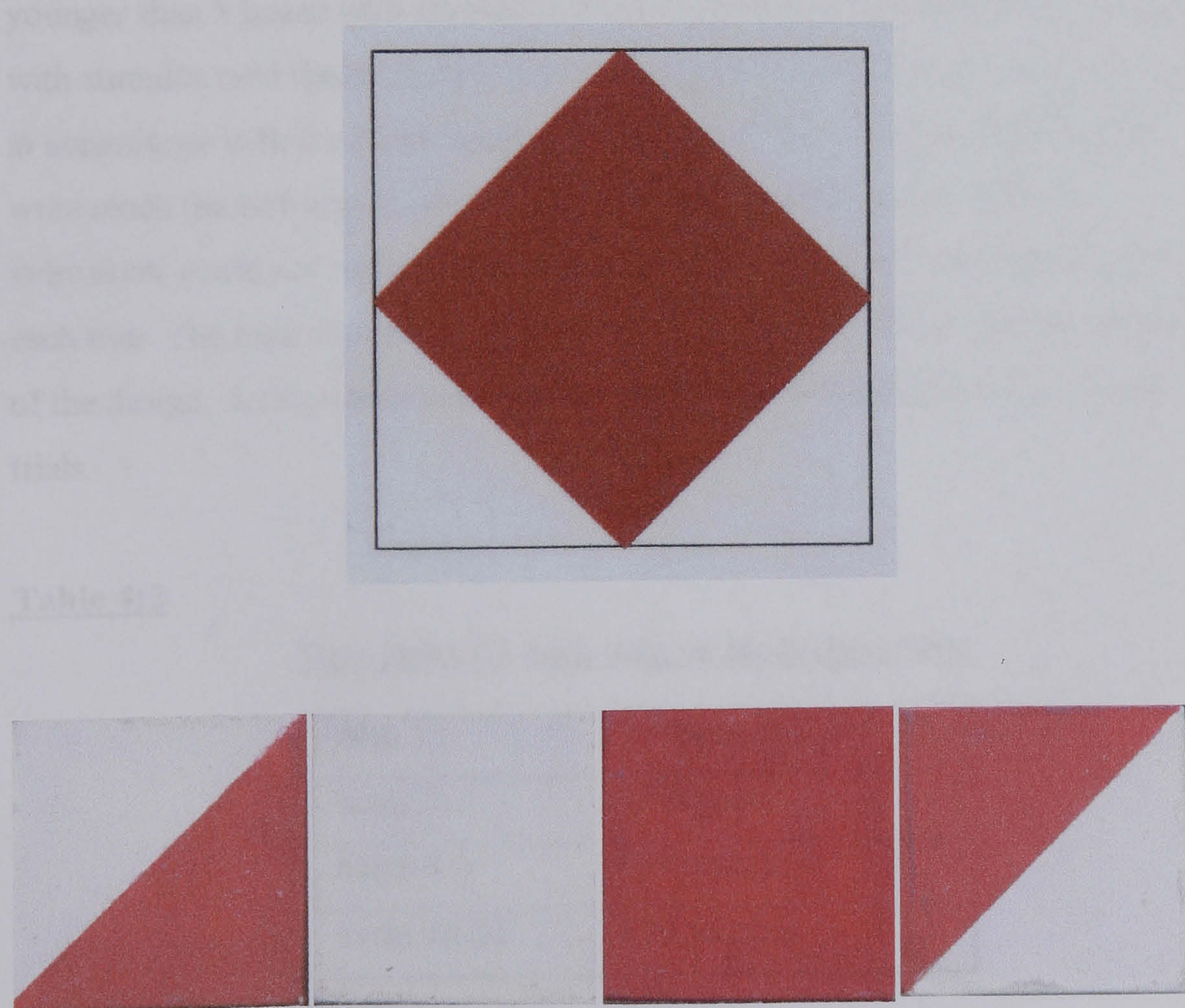
Subjects were given as much time as necessary to complete all 24 trials. Following each trial the computer automatically recorded the participant's length of line or diameter of circle in number of pixels.

4:5 Block design task

Materials. Twelve patterned designs were placed on individual cards that were 10.5 x 10.5 centimetres in length (Wechsler, 1974). The patterns were approximately 28x55mm to 85x85mm in size, depending on the number of blocks needed to create the pattern. There were nine wooden blocks (32 x 32mm) which were all painted identically. Each had 2 red sides, 2 white sides, and 2 sides that were both red and white (see Figure 4:4 for illustration). Each stimulus was placed on its own page in a small photo album. A stop watch was also needed to record the time to solve each design.

Figure 4:4

Block design test



Procedure. The standard instructions for the Block design test were followed to familiarise the subjects with the blocks and task.

"See these blocks? They are all alike. On some sides they are all red; on some sides, all white; and on some sides, half red and half white. They can be put together to make a design like the one you see on the card. Watch me." [The experimenter demonstrates trial one. The blocks are then scrambled up and given to the child.]

"Now you make one like the one on the card. Go ahead." In cases where participants failed on trial one of a practice item the following was said. "Watch me again." [Experimenter demonstrates how to construct the design.] "Go ahead. See if you can do it this time."

Each individual started with the appropriate practice trial for their age. Children younger than 8 began with stimulus card one, and those aged 8 and over began with stimulus card three. Any errors on practice trials (items 1-3) were dealt with in accordance with the block design test manual. When 2 consecutive failures were made the test was discontinued. A trial was recorded as incorrect if individuals could not replicate the correct design within the given time limit for each trial. The time allotted to solve the puzzle increased along with the difficulty of the design. A stopwatch was used to record time to complete design for all trials.

Table 4:2

Time limits for each item on block design test

item 1	30 seconds
items 2-5	45 seconds
items 6-9	75 seconds
items 10-12	120 seconds

On practice items individuals were allowed 2 attempts to solve the design. These were only counted as a failure if both trials were unsuccessful. Therefore, those beginning with item 1 would keep on with the test so long as they did not meet the discontinue criterion. If an individual started with card three and correctly solved the design on their first attempt they proceeded to the next test item. They did not have to do trials 1 and 2 although they were awarded the full points for them (2 points for each). If the person did not succeed on their first try on item 3 within the 45 second time limit they were given another chance to solve the design. Regardless of how an individual performed on the second trial of test item 3, items 1-2 were administered.

Coding . Successful completion on any of the practice stimuli for trial one earned 2 points. One point was given for correct construction on the second trial. Failure to make the design on both trials within the required time limit gave a score of 0. On the actual test items (4-12), points were awarded according to the time taken for completion (see Table 4:3). No credit was given for designs that were partially correct or incomplete. All points were totalled for items 1-12, allowing an individual to attain a maximum of 69 points.

Table 4:3

Awarding of points for performance on the block design test

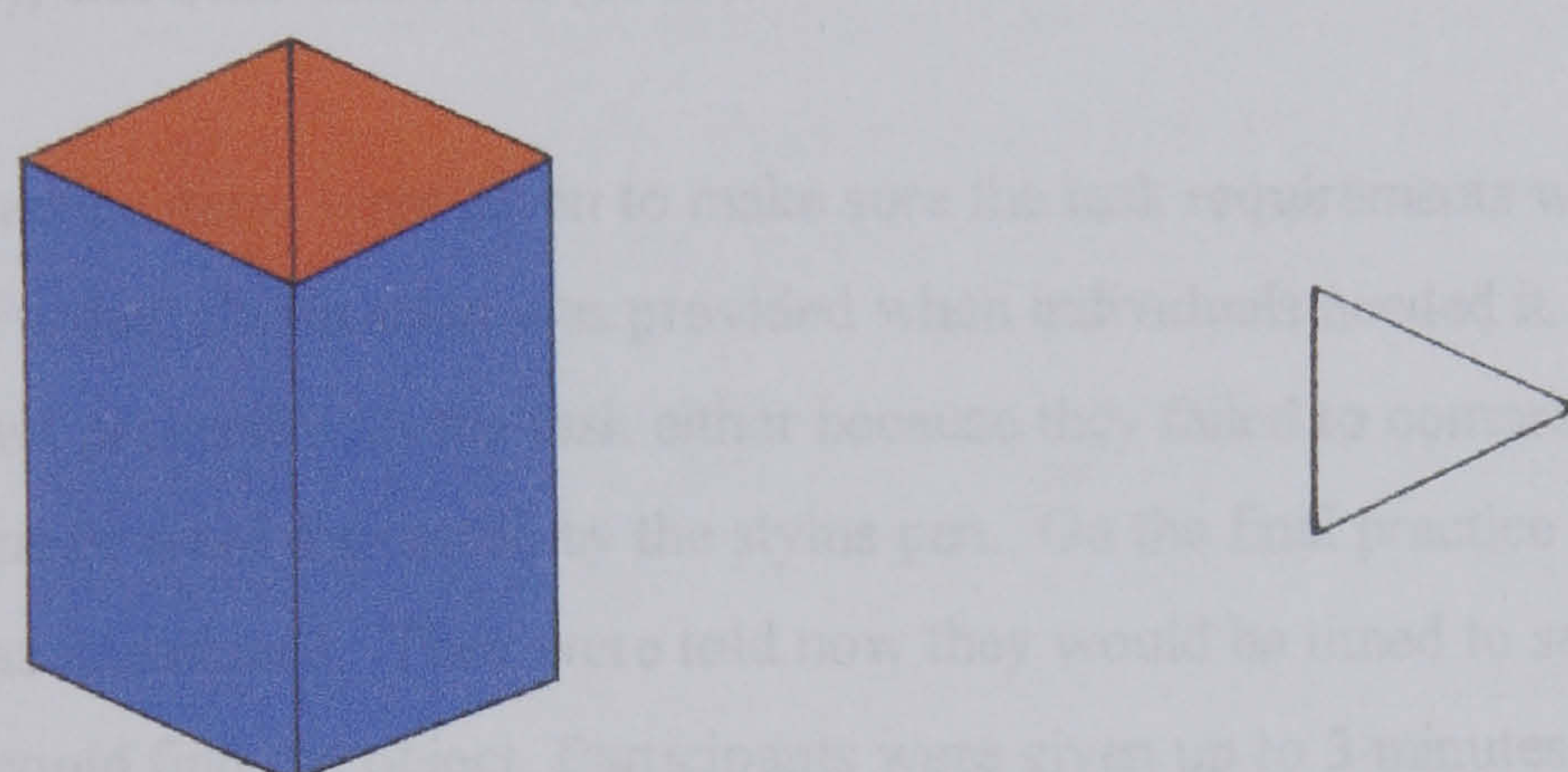
Item number	Completion time in seconds			
4	1-5	6-10	11-15	16-45
5	1-10	11-15	16-20	21-45
6-8	1-10	11-15	16-20	21-75
9	1-10	11-15	16-25	26-75
10	1-25	26-30	31-40	41-120
11-12	1-30	31-35	36-55	56-120
Score	7	6	5	4

4:6 Embedded figures test

Materials. Since the children's embedded figures test (CEFT) was discontinued and could no longer be purchased, the standard adult embedded figures test was used (Witkin, Oltman, Raskin, & Karp, 1971). The embedded figures test manual states that the test can be administered to younger children. Form A of the test was administered. There were 12 different complex cards. Each of these depicted a complex design that had a simple shape hidden within it. There were only 8 different simple shapes because some were common to a few of the complex designs. Each complex card was situated next to its appropriate simple shape on its own page in a small photo album. An example of one of the test items is shown in Figure 4:5.

Figure 4:5

Embedded figures test



Procedure. The standard procedure was adapted in a few ways to make it more appropriate for children and individuals with learning disabilities. Two additional practice trials were given initially to ensure that the individual understood the aim of the task (tent within pram, house within rocking horse). Performance on these trials was recorded but was not entered into the analyses. The following instructions were given to the participant.

"I am going to show you some pictures. Each time I show you one, I want you to describe it in anyway you like. Here is one (experimenter shows practice complex figure 1). Tell me what it looks like? OK. Then I will show you a smaller shape that is hidden inside this one (simple shape is revealed). Your job will be to try and find this hidden shape in the larger picture. I want you to tell me as soon as you see the hidden shape, and then use this pen (stylus) to show me where it is. Let's try this one. Can you see where the hidden shape is?"

If they were unable to find it the experimenter showed them and traced the shape with the pen. It was decided that the additional processing load required to search for the target object from memory (as in the standard adult task) would be too difficult for our chosen populations. Therefore, the target shape was not covered up when the participant was searching for it in the complex figure. This allowed the participant to refer to the target object whenever they needed to. This convention is part of the children's embedded figures test used by Brian and Bryson (1996), and Shah and Frith (1983).

Two more practice items were given to make sure the task requirements were understood. Further clarification was provided when individuals needed it. A few subjects did not proceed with the task either because they failed to comprehend the instructions or were distracted by the stylus pen. On the final practice item the stopwatch was introduced. They were told now they would be timed to see how quickly they could find the object. Participants were given up to 3 minutes to search for the target on the final practice card and the 12 test cards. After 3 incorrect guesses the person was presented with the next test item. This was to prevent frustration or random guessing.

The 12 test items were given in a fixed order for every subject . Complex figure 7-F was presented first after the practice items, and then the other cards were shown in sequence (1-A, 2-B, 3-C...). This presentation order was suggested in the embedded figures test manual to be more appropriate for younger children. If the individual was having considerable difficulty finding hidden objects on the first five items, the remainder of the test was administered on a separate day. This was to avoid frustration or reduced motivation which might result from several consecutive failures. Verbal encouragement was provided throughout the test to also prevent this.

Coding. If an individual failed to find the target item after three attempts or within the allotted 3 minutes their solution time was recorded as 180 seconds. An average completion time was calculated from the 12 test items (not practice items).

4:7 Rey figure test

Materials. The materials for the Rey complex figure test include the stimulus card (see Figure 4.3), recognition test stimuli, blank sheets of paper, pencil, rubber, and a stopwatch (Meyers & Meyers, 1995) . The stimulus figure is printed black on a white card (A4) which is laminated. The figure is presented in portrait orientation and is approximately 15cm x 12cm in size. The recognition stimuli come from pages 7-10 of the Rey test booklet. These pages display 24 items, 12 of which were actually part of the Rey stimulus card and 12 which were not (see Appendix 4:1). These stimuli were also black ink printed on white A4 sheets. Each of the 24 items had a corresponding number to identify it.

Procedure. There were actually four parts to the standard Rey figure test: the copy trial, immediate recall trial, delayed recall trial, recognition trial. The delayed recall trial was not administered since it required a delay of 30 minutes and would have prolonged the testing period considerably. This did not seem appropriate for our selected populations that included many individuals whom were young and had learning difficulties. The other three parts of the test were presented in the same order. The experimenter told the participant that we were going to do some drawing. It was important that they were not informed initially about the recall or recognition trials.

Copy trial. Participants were given a blank sheet of paper, pencil, and rubber. They were then shown the stimulus card and told to "copy the figure on to the piece of paper". The experimenter reminded them to try to do their best to draw the figure just as it was on the card. The stopwatch was then started and the participant was told to begin. As they drew the figure, the experimenter copied everything the person was drawing in the exact same way. The order in which each line was made was noted by increasing numbers (1,2,3...). Arrows were used by the experimenter to indicate the direction of the drawing strokes. When the participant said they had finished the timer was stopped and recorded.

Immediate recall trial. After the copy trial the timer was set for 3 minutes. The individual was told we were going to take a short break before doing the next part. During this time the experimenter spoke with the participant about daily activities at school. After the delay the individual was given another blank sheet of paper. The experimenter then said:

"Remember the picture I had you draw just a short time ago? Well, I want you to try and draw it again for me, but this time from memory. So try your best to draw as much as you can remember from the picture on this paper. Let me know when you have finished."

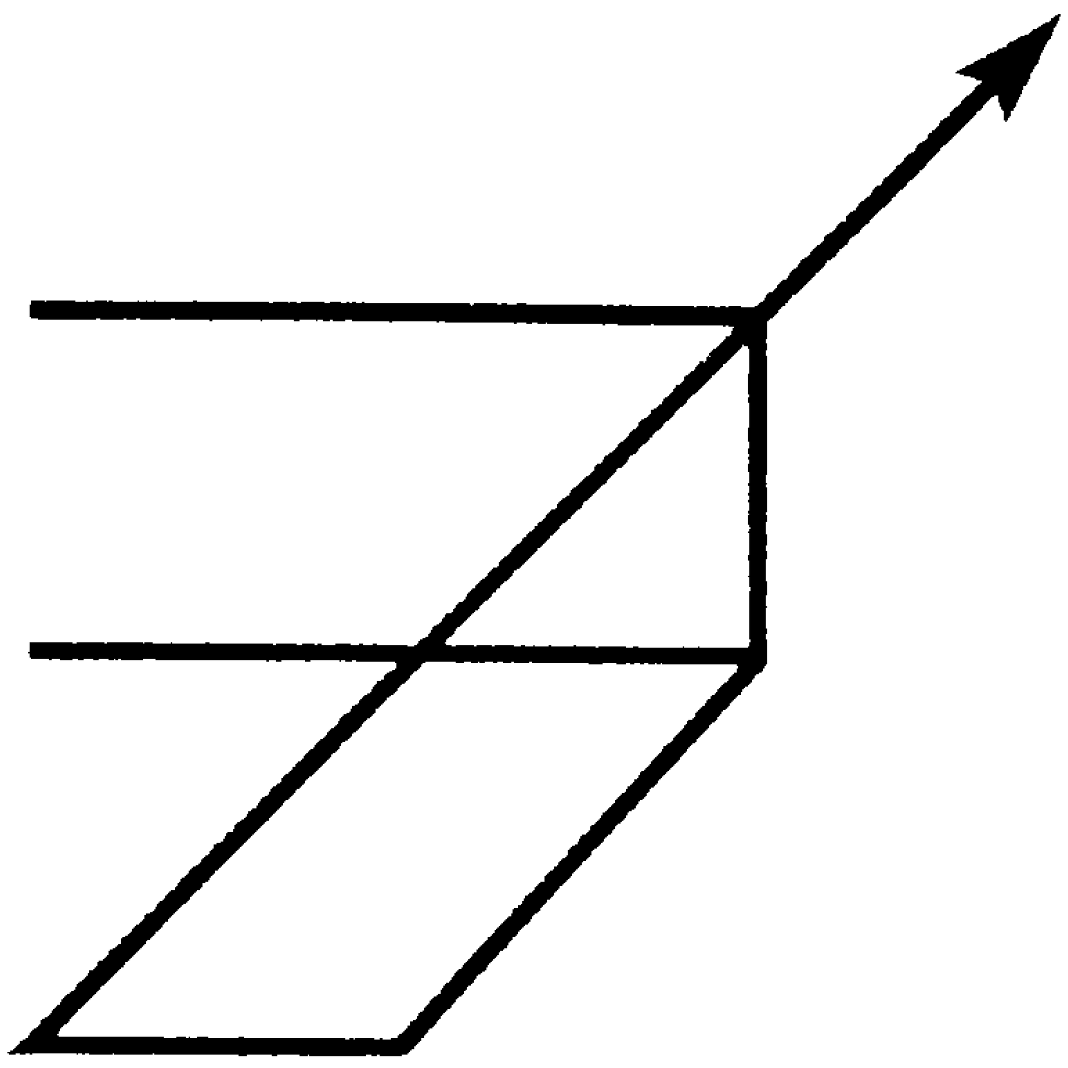
The timer was then started and the individual was instructed to begin. The experimenter copied everything the participant was drawing as on the copy trial. Once again numbers and arrows were used to indicate how the figure was being drawn by the person. When they had finished, their time was recorded.

Recognition trial. Immediately after the recall trial, the recognition stimuli were presented. Participants were told the following. "Some of these designs that are printed on these pages were part of the picture I asked you to copy earlier. They will be the same size and facing the same way as they were on that picture. I want you to point to only those designs you remember seeing." The number of each design the participant chose was recorded. Twenty-two of the 24 designs related to components of Rey complex figure. These could be considered to be local details (see Appendix 4:1). The remaining 2 designs reflect the outline of the entire figure and therefore are global shapes. Figure 4:6 shows examples of correct and incorrect local and global designs. Both types of designs will be considered together as well as individually in the results section.

Figure 4:6

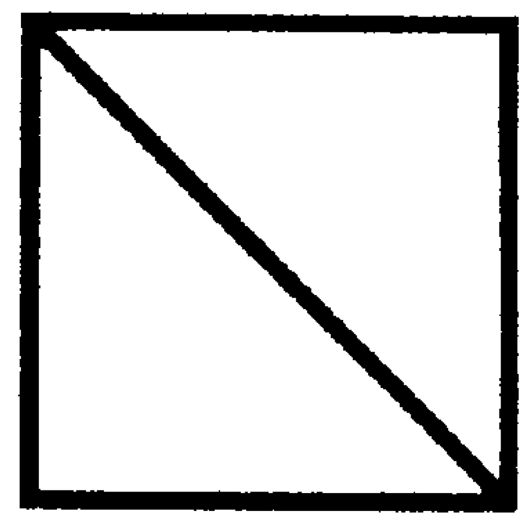
Examples of correct and incorrect designs for the Rey recognition test

11.



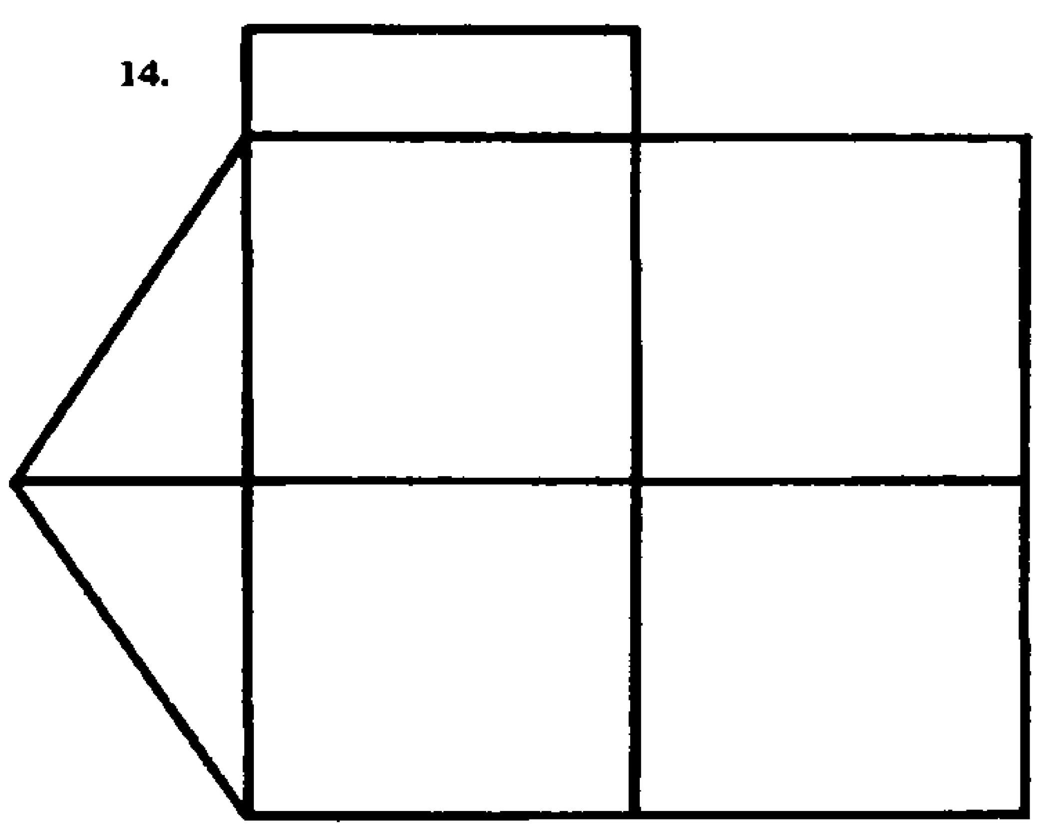
Incorrect local design

12.



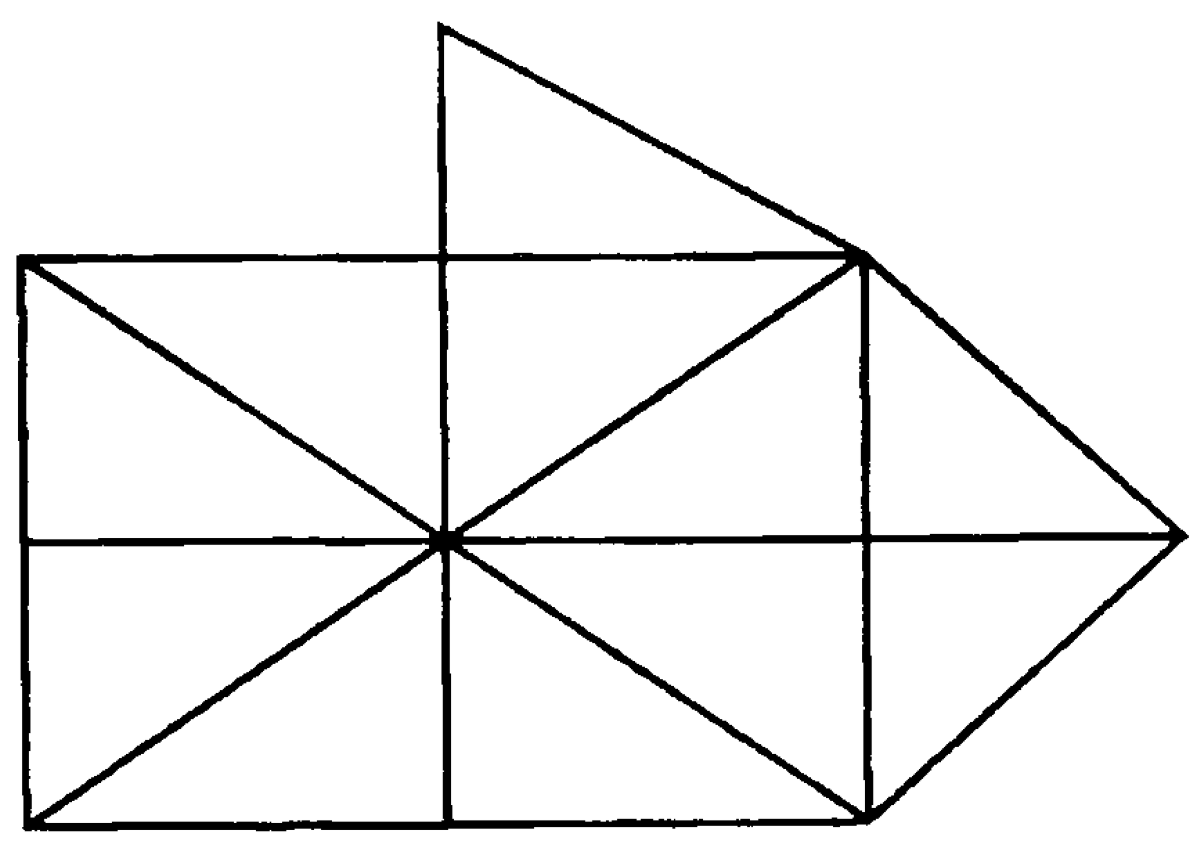
Correct local design

14.



Incorrect global design

15.



Correct global design

Coding. The standard coding procedure as specified by the manual was followed. The Rey figure was divided into 18 separate units which were assessed individually according to accuracy and placement. If an item was drawn accurately and placed correctly then a total score of 2 was given for that item. However, if that item is unnecessarily duplicated in the drawing then it is only given a score of 1. One point was awarded if the design was drawn accurately, but placed incorrectly. If the unit was in the correct place but drawn incorrectly then it was also given 1 point. In cases where the design is recognisable but is neither drawn or placed correctly then a score of 0.5 is assigned. When the individual has omitted the item altogether no points were earned. Therefore, each participant could obtain a score between 0-36 on the copy trial and on the immediate recall trial. On the recognition trial the number of correctly identified designs (out of 12) was added to the number of those that were correctly rejected (out of 12). This total score was entered into the analysis.

There were other comparisons I was interested in making that were not part of the standard analyses suggested in the Rey figures test booklet. Firstly I wanted to know whether there were group differences in the drawing style individuals displayed. More specifically, were they using a global or local strategy? If an individual is using a global strategy they will tend to focus on drawing the outline of the entire figure first and then move on to filling in the internal details. A local strategy might then entail a person focusing on drawing the secondary details and paying little attention to the larger global shape of the figure. Two people were asked to judge which strategy they felt individuals were using on the copy trial. They were able to do this by looking at the experimenter's notes that indicated the order and direction in which the lines were drawn.

I was also interested in knowing whether individuals imposed meaning on what they were drawing. This might be reflected by the person drawing something that does not actually appear in the Rey figure. For instance, the overall figure somewhat resembles a house. A person might then include windows or a door in their drawing which would indicate that they interpreted the figure to have meaning. It could be that groups differ in whether or not they incorporate meaning in their drawings. In particular, one might expect those with autism/Asperger's syndrome to use meaningful representations less in their drawings. Two people were asked to rate whether they thought an individual used meaningful representation in their drawings on both copy and recall trials.

Recognition test. This tests the participant's memory for elements of the complex figure. It also helps to assess an individual's ability to use cues for retrieval (other recognition memory studies include Brian and Bryson, 1996; Ameli, et al., 1988). Both these studies found that meaningful information did aid memory recall in autistic individuals. As with control participants, they were better at correctly recognising meaningful stimuli than non-meaningful stimuli. The elements in this particular recognition task however are devoid of meaning. Are individuals with autism better at recognising the smaller individual elements rather than the larger general shape in comparison to controls? This should partly be related to how they drew the complex figure. For instance if they drew the figure piece by piece using several lines to construct the figure, this would suggest they were breaking it into very small chunks. However, they may instead draw the general shape first and then fill in the detail.

4:8 Results on illusion task

Five autistic individuals did not complete all 4 illusions. A computer malfunction that resulted in the loss of data on a particular illusion accounted for 4 of these. The data for only one illusion was excluded in these individuals. Another individual was excluded because he was unwilling to continue with the testing. Data for this individual were collected for only 2 of the illusions. Raw data were transferred directly into SPSS from the computer program and mixed ANOVA's were carried out on each of the illusions separately. Condition (2) and trial (3) were included in the analysis as within subjects factors and participant group (5) was entered as a between factor. This would allow us to assess whether performance in general differed on the illusion and control trials. This analysis would also allow us to detect any group differences in performance on either condition. Individuals with autism might differ from other participants in their performance on illusion trials but not on control trials. This would occur if there were differences in judgments between conditions specifically in individuals with autism. Hence, a group by condition interaction was expected.

Titchener Circles

Figure 4:7 displays the group means for the illusion and the control condition. The figure shows that all groups scored lower on the illusion than the control, which suggests that the effect of the illusion led to a systematic distortion in perception. The horizontal line drawn across the graph indicates the actual number of pixels the circle being judged was in size. This was apparent as a main effect of condition $F(1,79)=30.653$, $p<.001$. There was also a significant difference between groups $F(4,79)=5.587$, $p<.005$. A Tukey's HSD post-hoc test showed this was due to the autistic group having overall significantly higher scores (combined over trial and condition) than the MLD and year 3 groups. There were no other significant main effects. Although a significant group by condition interaction was not found I wanted to be certain that each group individually judged differently on the illusion and control trials. Therefore, t-tests were carried out on each group separately as in Study

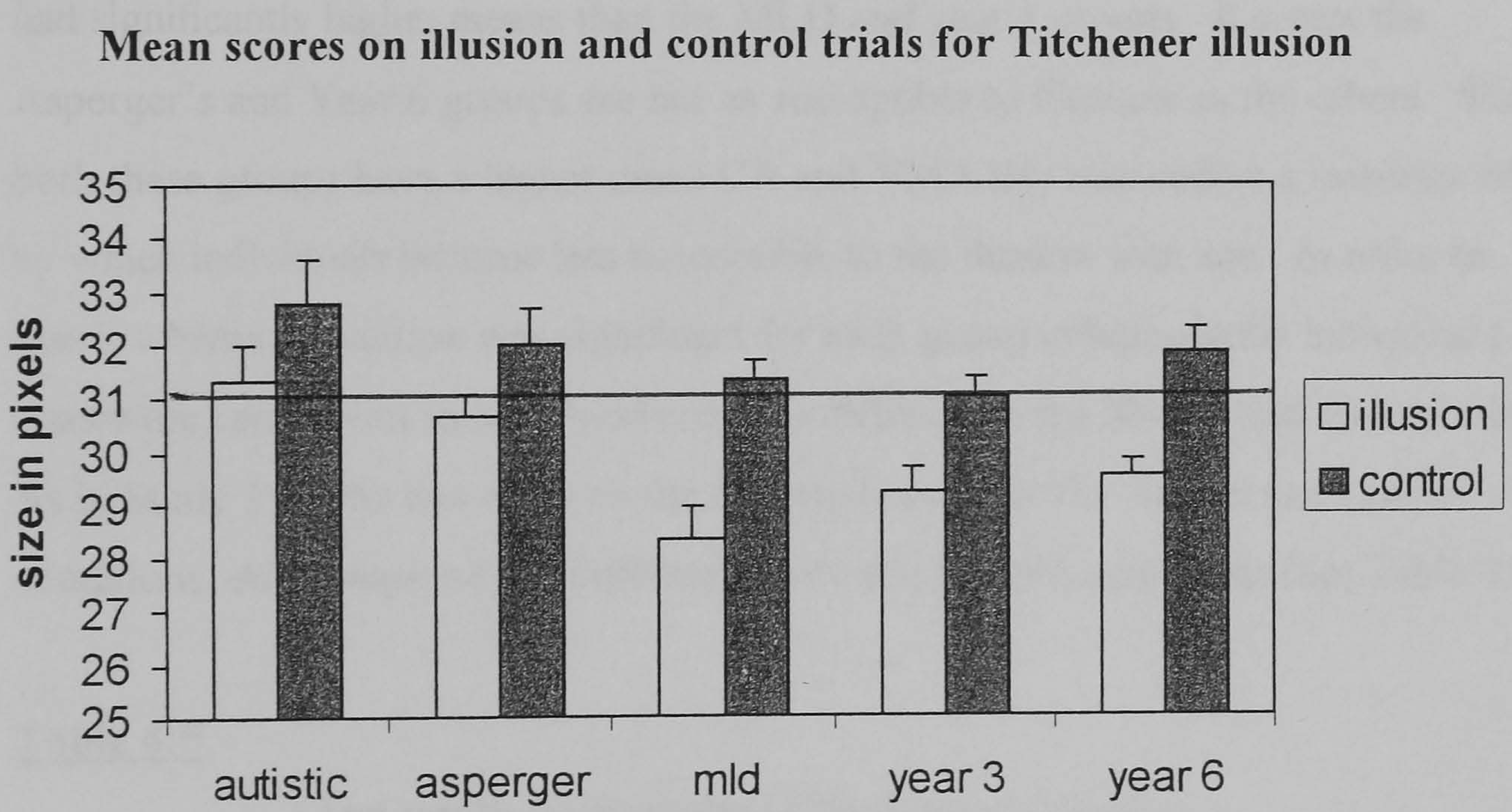
3:1 comparing performance on the first trials of both conditions. All groups judged significantly differently between the illusion and control trials (see Table 4:4).

Table 4:4

t-test results for first trial of Titchener illusion

Group	Significance
Autistic	t= -2.19 (17), p<.05
Asperger	t= -2.86 (9), p<.05
MLD	t=.-3.01 (19), p<.01
Year3	t= -2.56 (17), p<.05
Year6	t= -3.26 (17), p<.01

Figure 4:7



Muller-Lyer

Figure 4:8 displays group means for the illusion and control condition. The figure shows that all groups scored lower on the illusion condition than on the control, which suggests they were susceptible to the illusions. Again the horizontal line indicates the actual size in pixels of the line being judged. Our analyses supported this showing a significant main effect of condition $F(1,81)=495.125$, $p<.001$. Trial was also significant $F(2,162)=8.03$, $p<.001$. This was a result of the means for each successive trial being higher. There was a main effect of group $F(4,81)=3.225$, $p<.017$ and this factor interacted with condition $F(4,81)=7.133$, $p<.001$. Further analyses revealed that the interaction was due to groups performing significantly different on the illusion condition $F(4,85)=6.174$, $p<.001$.

A post-hoc test (Tukey's HSD) revealed that both the Asperger's and year 6 groups had significantly higher means than the MLD and year 3 groups. It seems the Asperger's and Year 6 groups are not as susceptible to illusions as the others. Since both these groups have a higher mean CA and VMA this may reflect a maturity effect by which individuals become less susceptible to the illusion with age. In order to check whether condition was significant for each group independently individual t-tests were carried out to see if performance differed on the illusion and control trials. As in Study 3:1, this was done on the first trials only for the illusion and control conditions. All groups judged differently between the two conditions (see Table 4:5).

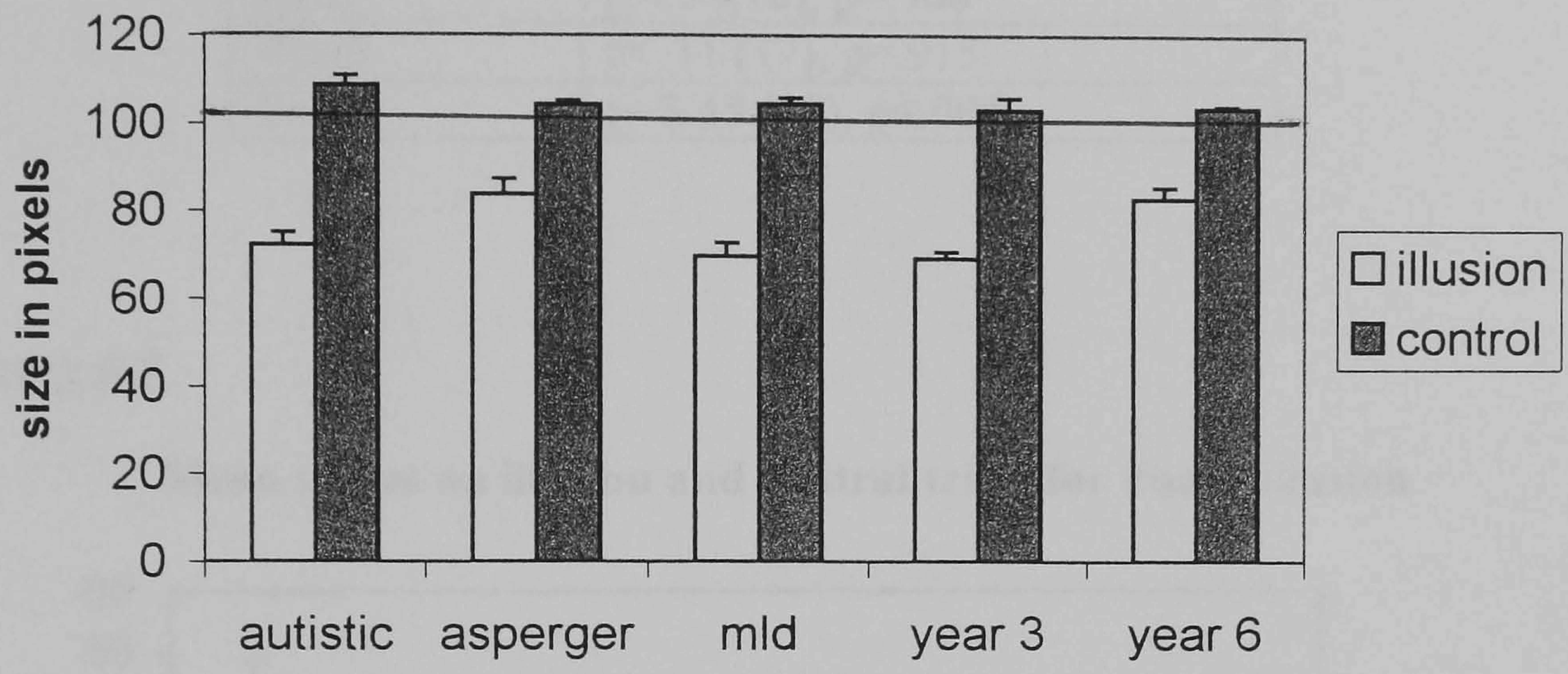
Table 4:5

t-test results for first trial of Muller-Lyer illusion

Group	Significance
Autistic	$t=-11.94$ (17), $p<.001$
Asperger	$t=-5.57$ (10), $p<.001$
MLD	$t=-10.47$ (19), $p<.001$
Year3	$t=-11.60$ (18), $p<.001$
Year6	$t=-7.90$ (17), $p<.001$

Figure 4:8

Mean scores on illusion and control trials for Muller-Lyer illusion



Ponzo

The Ponzo differed from the other illusions in that susceptibility to the illusion would result in overestimation rather than underestimation of size. This can be seen in Figure 4:9 which displays the means for each group on both conditions. All groups systematically overestimated on the illusion condition. The horizontal line indicates the actual size the judged circle was in pixels. This was confirmed by a main effect of condition $F(1,79)=15.976$, $p<.001$. T-tests were carried out on the first trials of both conditions to ensure the effect could be found for each group separately. The results showed that only year 6 and the autistic group performed significantly different on the two conditions (see Table 4:6). No other effects were significant.

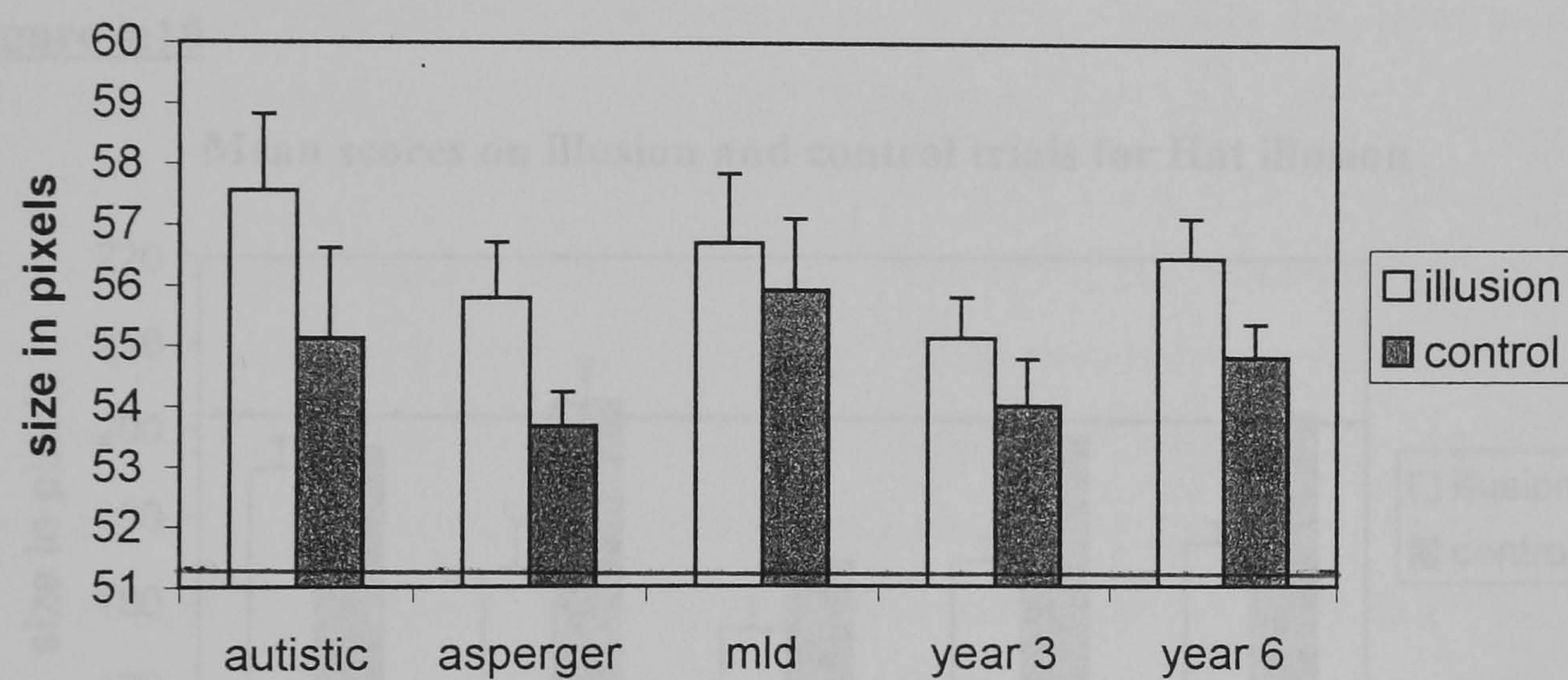
Table 4:6

t-test results for first trial of Ponzo illusion

Group	Significance
Autistic	t= 2.22 (17), p<.05
Asperger	t= 1.31 (10), p=.221
MLD	t=-.04(18), p=.968
Year3	t= .11 (17), p=.915
Year6	t= 3.55 (17), p<.005

Figure 4:9

Mean scores on illusion and control trials for Ponzo illusion



Hat

The mean scores for each condition are displayed in Figure 4:10. All groups underestimated size on the illusion condition. The actual size of the line being estimated is shown by the horizontal line. As with the other illusions, there was a significant effect of condition $F(1,79)=37.966$, $p<.001$. There was also a significant difference between groups $F(4,79)=5.483$, $p<.005$. Post-hoc comparisons showed that participants in the MLD group had overall lower scores (combined across trial and condition) than the other groups. There were no other significant main effects. Individual t-tests on the first trials were carried out to compare each group's performance on the illusion and control conditions. The results showed that the MLD group and year 6 all judged differently between conditions to a significant extent (see

Table 4:7). The remaining groups however did not perform differently on the two conditions.

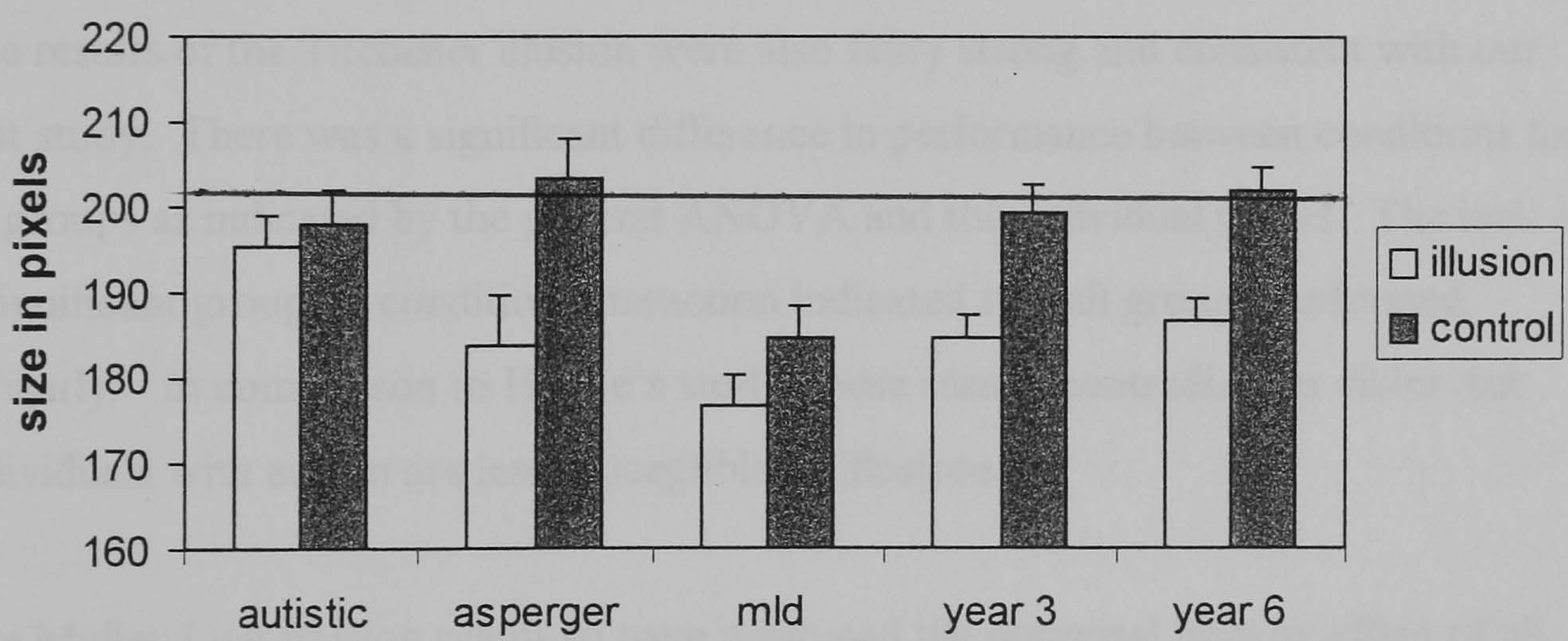
Table 4:7

t-test results for first trial of Hat illusion

Group	Significance
Autistic	t= .24 (16), p=.811
Asperger	t= -1.04(9), p=.327
MLD	t=.-4.31(19), p<.001
Year3	t= -1.36 (18), p=.190
Year6	t= -3.35 (17), p<.005

Figure 4:10

Mean scores on illusion and control trials for Hat illusion



4:9 Interim Discussion

These results provide little support for Happe's claim that individuals with autism are not susceptible to illusions. In general, there was a significant main effect of condition on all illusions which suggests that individuals judged differently on the two conditions. This is consistent with the results obtained in Experiment 3:1. However, not all groups judged differently between conditions to a significant extent as revealed by further analyses. A discussion of the results from each illusion individually will help us determine to what extent they support Happe's argument.

On the Ponzo illusion there was no evidence of group differences from the general ANOVA. However, the t-tests on the first trials of both conditions suggested some differences in susceptibility to illusions. There was no significant contrast between conditions in those with Asperger's syndrome, though they did succumb to it in Experiment 3:1. The pattern was reversed for the autistic group in that they were susceptible in this study but not in the first. This may weakly offer some evidence for Happe's argument even if there is inconsistency between the two studies. However, this does not seem to be specific to autism since other non-autistic groups were also not susceptible to this illusion. The results from the Ponzo illusion seem to be less clear than those from the Muller-Lyer and Titchener illusion.

The results of the Titchener illusion were also fairly strong and consistent with our first study. There was a significant difference in performance between conditions for all groups as indicated by the general ANOVA and the individual t-tests. The lack of a significant group by condition interaction indicated that all groups performed similarly. In comparison to Happe's study, these results contradict her claim that individuals with autism are less susceptible to illusions.

The Muller-Lyer illusion seems to have produced the strongest illusory effect of all the stimuli. Although the results showed a significant difference between groups on the illusion condition, this was not due to the autistic/Asperger group being less susceptible to the illusion. Furthermore, as in Experiment 3:1, all groups significantly judged differently on the t-tests. These findings are consistent with Happe's, as the Muller-Lyer was the one illusion she found individuals with autism to be susceptible to. She argued this may not be ideal as it did not allow one to easily distinguish between "induced figure and inducing context".

For example, in the Ponzo illusion the diagonal lines provide the inducing context that distorts the appearance of the circles that lie between them. The circles in this case would be the induced figure. Thus, the inducing context (diagonal lines) and the induced figure (circles) are separated by space in this illusion. This is also the same for the Titchener Circles. However, in the Muller-Lyer the arrows which create the inducing context in the illusion are connected to the induced figure and form part of the same object. Happe argues that it is difficult to separate the illusion into these two elements since coherence is inherent in the configuration of the illusion. She argues this would explain why the illusory effect was found in those with autism.

The same could be argued however for the Hat illusion. There does not seem to be an obvious context that needs to be integrated for the illusion to work like there is in the Ponzo or Titchener illusions. Rather, the orientation of the lines is sufficient to induce perceptual distortion. On this basis Happe would have to predict that individuals with autism would be susceptible to the Hat illusion. It is ironic that there was some evidence of less susceptibility on this illusion in the current study.

Although there was a main effect of condition on the Hat illusion which indicated that all groups performed significantly different on the two conditions, a look at the individual t-tests showed that those with autism and Asperger's syndrome were less susceptible on the illusion. However, since this was also true of those individuals in year 3, non-susceptibility is not confined to those with autism/Asperger's syndrome. In Experiment 3:1 there was also some evidence that those with autism and Asperger's syndrome were less susceptible to this illusion.

Overall, it seems that performance on the Titchener illusion provides the strongest support against Happé's argument. The results of the Ponzo and the Hat illusion are somewhat inconclusive. Susceptibility to the Muller-Lyer in the autistic group is consistent with Happe's findings. However, she dismisses this as evidence against her theory by arguing that the illusion is not ideal to test WCC, as the context is not easily separated or identified.

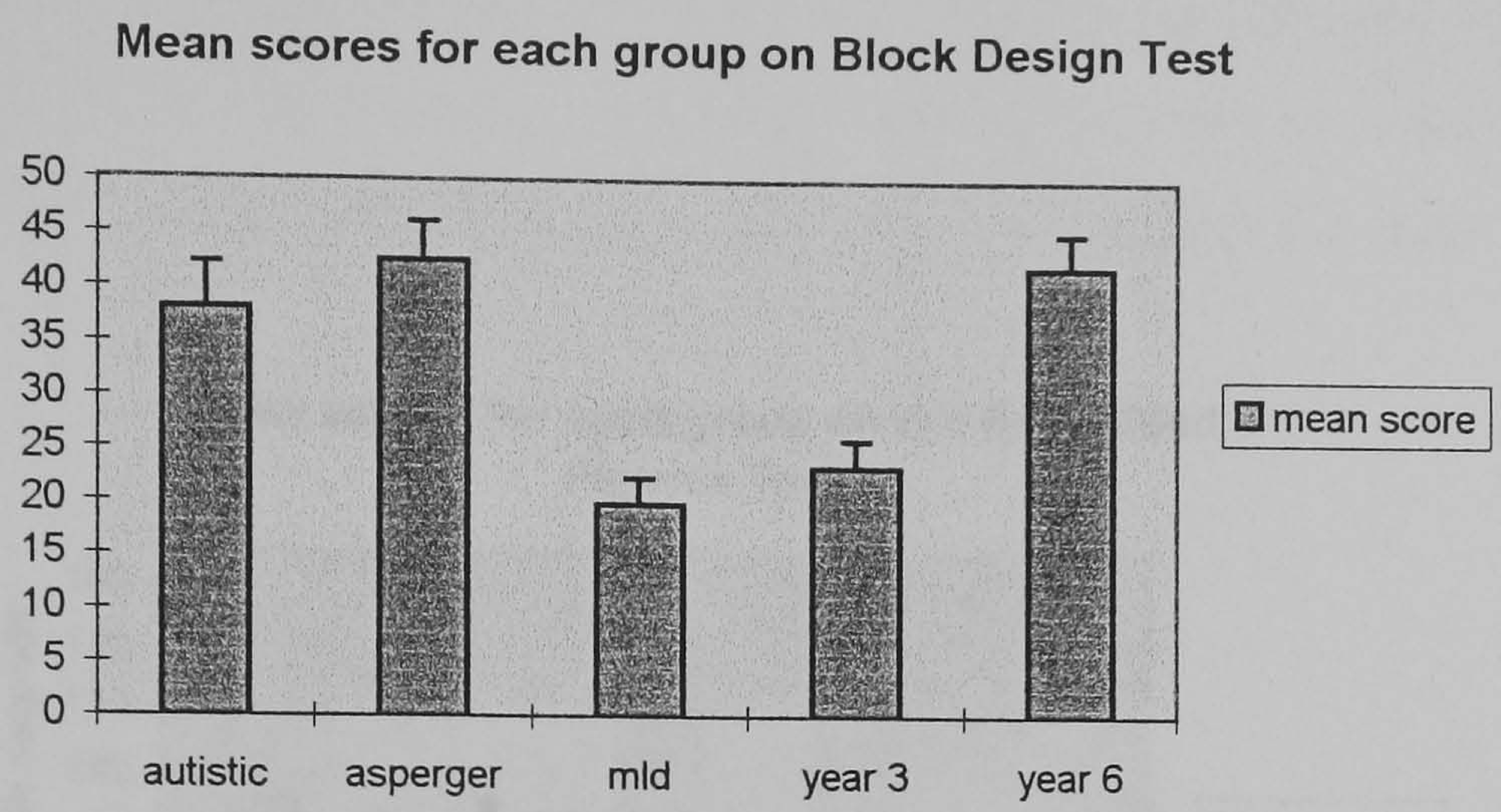
The reason for this study was not just to establish whether or not individuals with autism succumb to illusions, but to see whether performance on the illusions correlates with measures of central coherence. I will address this question later.

4:10 Block design test

Each individual's score on the block design test was entered into a oneway ANOVA with group (5) as a between subjects factor. The analysis revealed there was a significant difference between groups $F(4, 86)=11.114$, $p<.001$. Post-hoc comparisons (Tukey's HSD) revealed that the MLD and year 3 groups had significantly lower scores than the other groups. This difference is illustrated in Figure 4:11 which shows each group's mean score. The graph shows how the autistic group scored significantly higher on the block design test than their verbally matched controls, suggesting this area of functioning in autism may be preserved. Year 6 also did significantly better than Year 3 showing an expected increase in visuo-spatial ability with age. The individuals with Asperger's syndrome performed similarly to the Year 6 group, but did not surpass them on the task.

Since visuo-spatial ability tends to increase with verbal ability an ANCOVA was carried out to see if the results changed when VMA was entered as a covariate. For example, once VMA is controlled for, those with Asperger's Syndrome might gain higher scores in block design than those in year 6. However, the pattern of results remained the same as in the previous ANOVA.

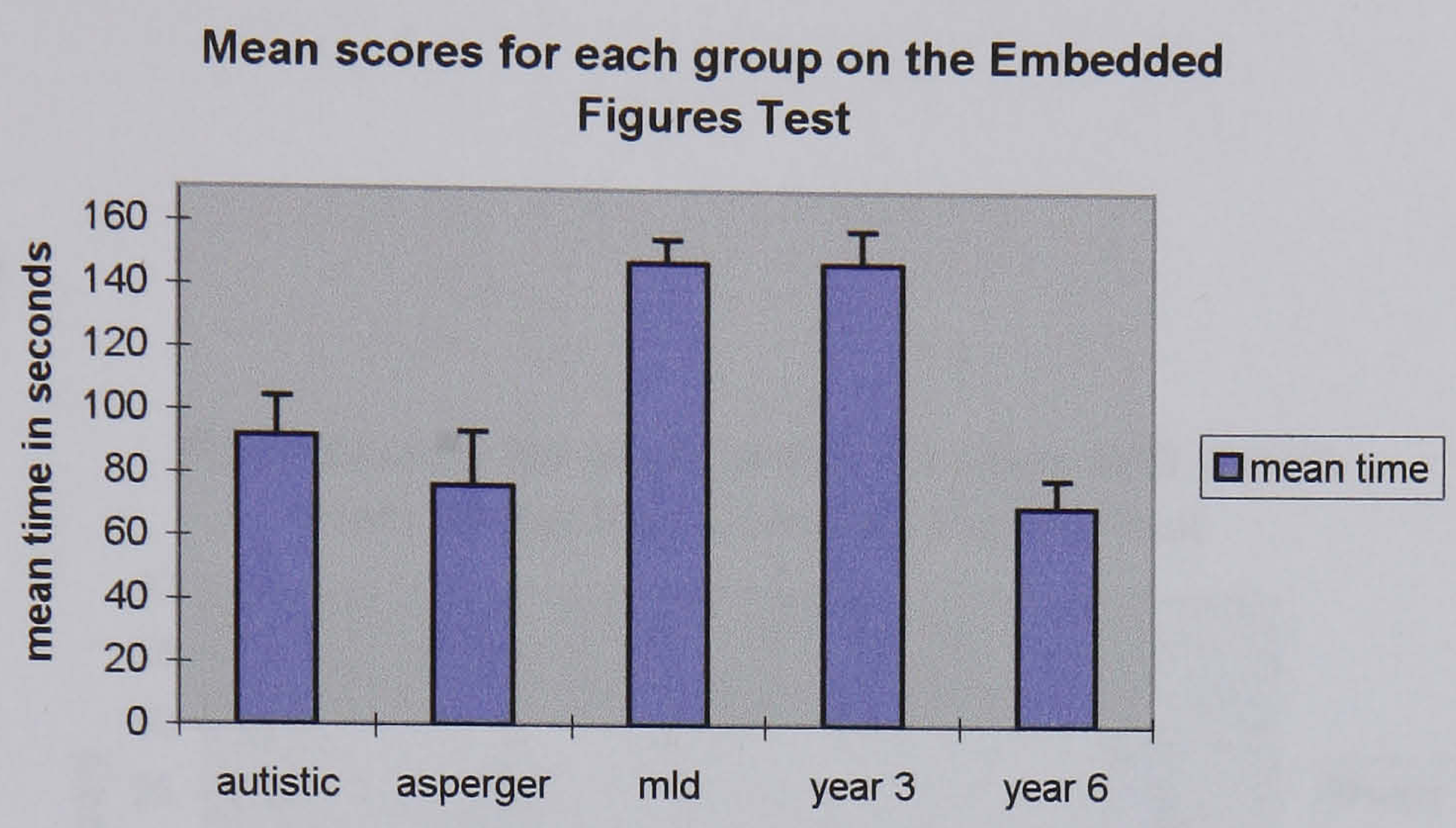
Figure 4:11



4:11 Embedded figures test

Each individual's average time to complete the embedded figures test was entered into a oneway ANOVA, with group (5) as a between subject factor. The results showed there was a significant difference between groups $F(4,84)=12.935$, $p<.001$. The difference in performance on this task is illustrated in Figure 4:12 which shows the mean scores of both conditions for all groups. A Tukey's post-hoc test revealed that the year 3 and MLD groups had significantly higher mean completion times than the other groups. It seems they had considerably more difficulty with this task than the Asperger's, autistic, and year 6 groups whose means were much lower. Although the autistic group took a bit longer to complete the task compared to the Asperger's and year 6 group, they still did significantly better than the MLD group. This provides further evidence that individuals with autism might excel in visuo-spatial ability. An expected increase in ability with age is also reflected in the better performance of year 6 in relation to the year 3 group. Again, individuals with Asperger's syndrome were comparable with those in year 6. An ANCOVA was carried out with VMA as a covariate, and the results remained the same.

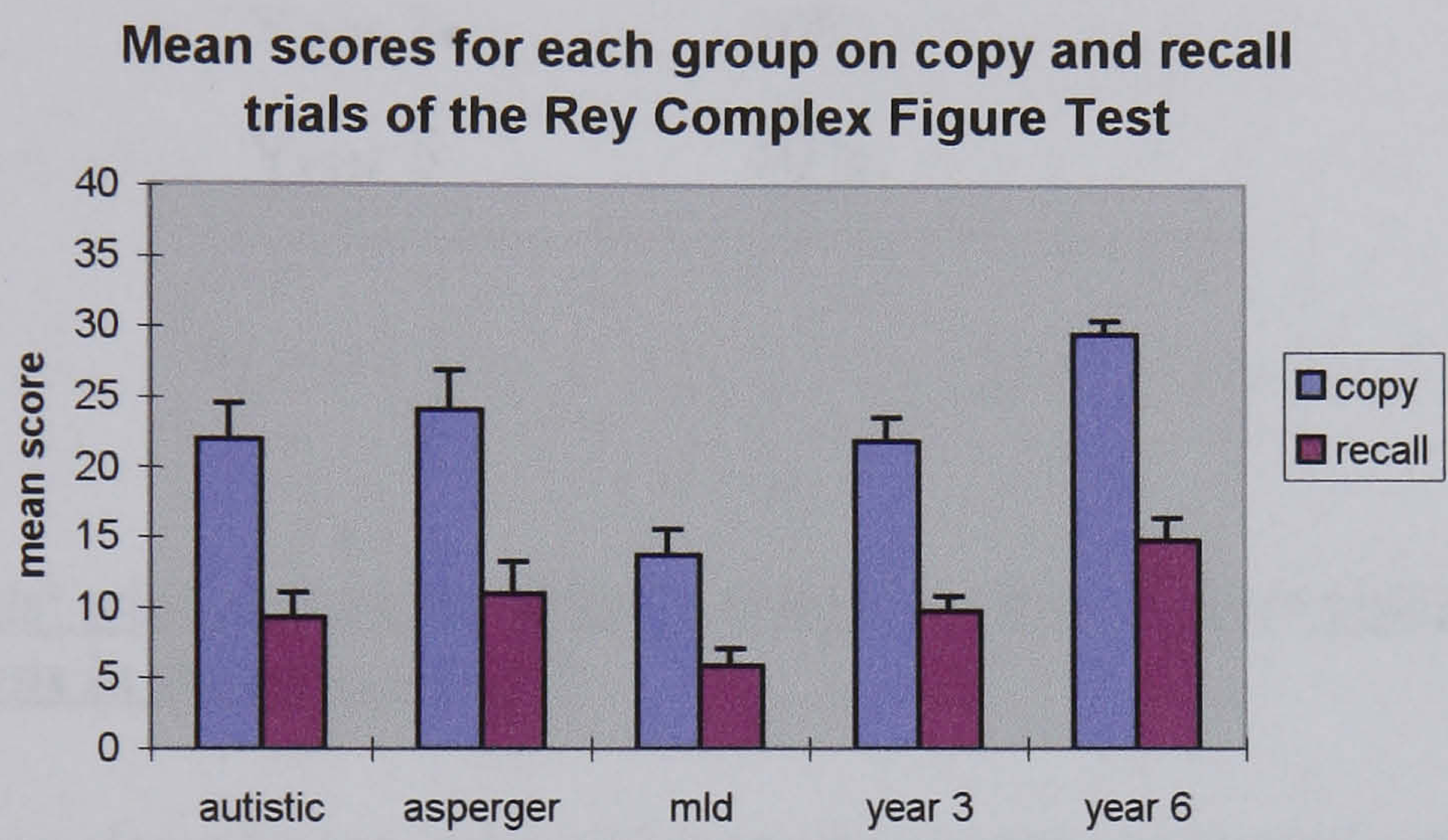
Figure 4:12



4:12 Rey complex figures test

Each individual's scores on both the copy and delayed recall trials were entered into a mixed ANOVA. There was a within subject factor of condition [(2) copy or recall] and a between factor of group (5). There was a significant main effect of group $F(4,82)=8.237$, $p<.001$ and condition $F(1,82)=281.073$, $p<.001$. There was also a significant interaction between these two factors $F(4,82)=2.894$, $p<.05$. The difference in performance on the two conditions is illustrated in Figure 4:13 which shows each group's mean score. Oneway ANOVA's were carried out on each condition separately to clarify the interaction. A significant difference in performance was found on the copy condition $F(4,86)=8.602$, $p<.001$. Post –hoc analysis (Tukey's HSD) showed this was due to the MLD group performing worse than all other groups. The analysis on the recall scores also yielded a significant difference between groups $F(4,86)=4.775$, $p<.005$. Post-hoc comparisons showed this was due to the MLD group doing significantly worse than year 6. Paired t-tests were carried out to see how each group individually performed on the 2 trial types. All groups achieved a significantly higher score on the copy condition ($p<.001$). As before an ANCOVA with VMA as a covariate on both the copy and recall trials was conducted. This did not change the pattern of results in anyway for either of these conditions.

Figure 4:13



Do individuals' with autism/Asperger's syndrome prefer to use a local or global strategy when drawing?

Two raters were asked to judge whether individuals used a global or local strategy when copying the Rey figure. An inter-rater reliability of 78% was established. The percentage of those using a global strategy was calculated on only the individuals where both raters were in agreement. Table 4:8 displays these percentages for each group. In order to see whether those on the autistic spectrum were less likely to use a global strategy. Surprisingly the autistic and Asperger's group used a global strategy at least as much as other groups.

Table 4:8

Percentage of individuals in each group using a global strategy

Group	% using a global strategy
Autistic	50%
Asperger's	60%
MLD	29%
Year 3	50%
Year 6	40%

Do individuals' with autism/Asperger's syndrome incorporate meaningful representations in their drawings?

Two raters were also asked to judge whether participants used meaningful representations in their drawing to see if those in the autistic/Asperger groups used representation less than comparison groups. There was an inter-rater reliability of 95 percent. Again, the figures shown in Table 4:9 are based only on those individuals the raters agreed upon. The use of representation was not particularly high in any of the groups, though the zero score in the Asperger group is notable. Individuals with autism however were just as likely to incorporate meaningful representations in their drawings as other groups. In general, there is no striking difference between groups in the use of representation.

Table 4:9

Percentage of individuals in each group who incorporate meaningful representations into their drawings

Group	% using representation
Autistic	11%
Asperger's	0%
MLD	25%
Year 3	6%
Year 6	13%

Rey recognition task

Global analysis

If individuals without autism are more inclined to attend to global shapes, then one might expect they would be accurate in their recall of the overall shape of the Rey figure. Table 4:10 shows how groups performed in their ability to identify the correct global design and reject the distracter. The majority of individuals in each group fell in the 'accept both' column. That is, they correctly identified the appropriate design but failed to reject the distracter. The first column shows that few individuals were able to both correctly identify the target and reject the distracter. There do not appear to be any notable differences between those with and without autism in their pattern of responses as displayed below.

Table 4:10

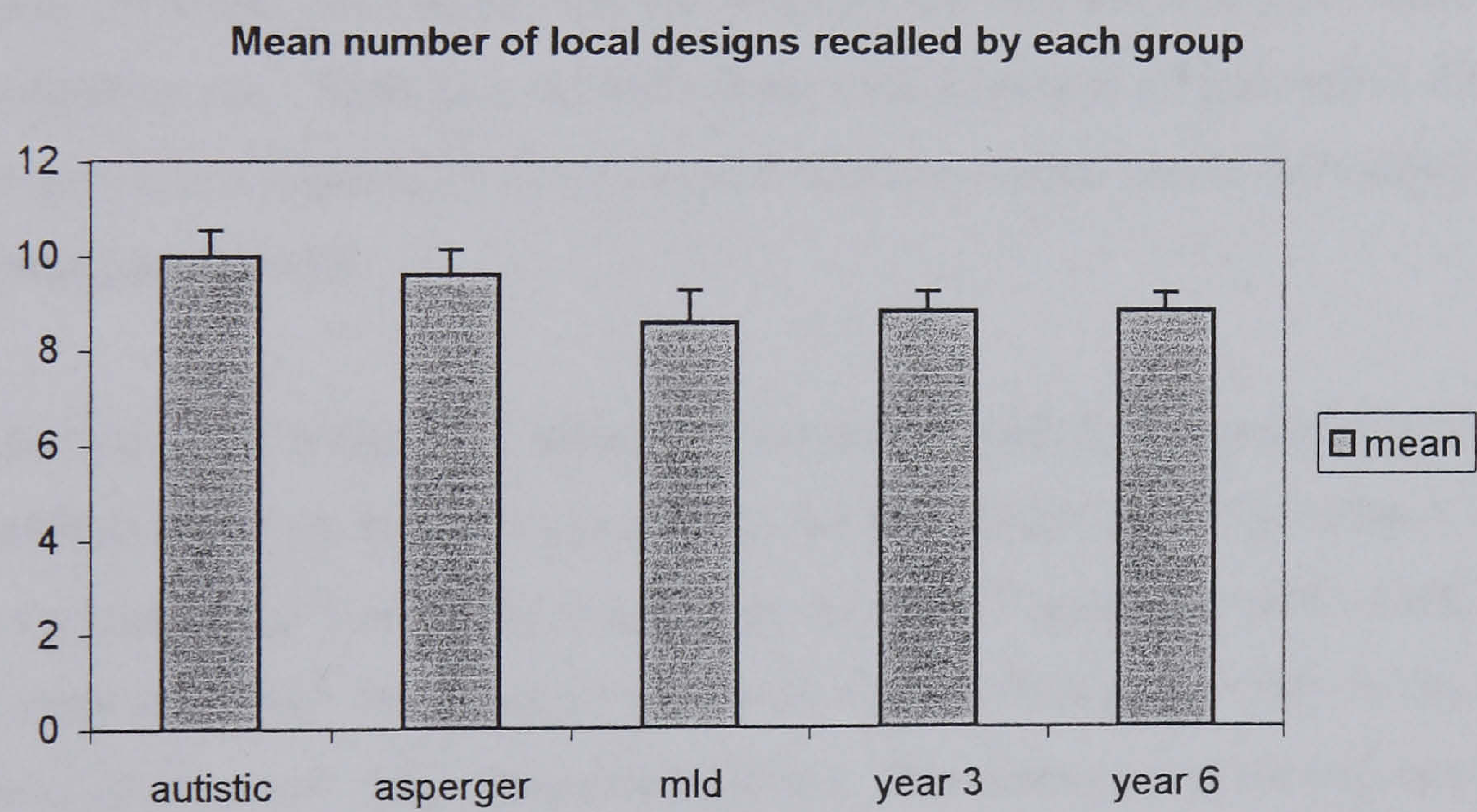
Number of individuals in each group accepting and rejecting target and distracter global shapes

Group	Reject distracter & accept target (both correct)	Accept distracter & reject target (both incorrect)	Accept both (1 correct)	Reject both (1 correct)
Autistic	5	1	11	1
Asperger	0	5	5	1
MLD	4	6	8	2
Year 3	2	5	12	0
Year 6	0	1	15	2

Are there group differences in recall of the local shape?

A oneway ANOVA was carried out to investigate whether there were any group differences in the ability to recall the components of the design that would be considered local. This meant the two global designs were removed leaving 22 items (11 target items and 11 distracters). An individual was awarded 1 point for each target item they correctly identified. One point was also given for each distracter they appropriately rejected. The total number of points (maximum of 22) was entered into SPSS. A between groups (5) ANOVA was performed which found no significant difference in performance. Group means are shown in Figure 4:14.

Figure 4:14



4:13 Discussion of central coherence measures

According to previous literature on WCC I predicted that individuals with autism and Asperger's syndrome would perform significantly better than comparison groups on the block design task and embedded figures test. It was expected that individuals with autism and Asperger's syndrome might perform better than other groups on the

Rey copy but not the Rey recall trial. Evidence of a local strategy and less use of representation in the drawings of the autistic and Asperger's group would show evidence of WCC. If individuals did process details more than global shapes this would also be obvious in their recognition of the parts of the Rey figure.

The results offer mixed support for the theory of WCC. On the block design test and embedded figures test the autistic group did perform significantly better than their VMA-matched controls. This is consistent with previous findings (Shah & Frith, 1983;1993). Since the male/female ratio for both these groups was similar, the better performance of the autistic group could not be explained by sex differences. However, individuals with Asperger's syndrome performed similarly to typically developing 11 year olds, but did not outperform them. This may be a result of their lower VMA (9;11) in comparison to the VMA (11;6) in the typically developing group. However, the results from the ANCOVA's with VMA as a covariate ruled this explanation out. Therefore, the individuals with Asperger's Syndrome in this study did not show a superiority effect on these tasks in comparison to individuals with typical development.

Individuals with autism and Asperger's syndrome performed significantly better than the MLD group on the Rey copy but not the Rey recall trial. No evidence was found to suggest that individuals with autism or Asperger's syndrome used a local drawing strategy less often. They seemed to rely on a global drawing strategy to the same extent, if not more, than comparison groups. This is not consistent with previous literature suggesting that individuals with autism tend to draw the internal details first rather than the outline shape (Mottron & Belleville 1993,1995; Steel, et al.1984; Prior & Hoffman, 1990). It is consistent with findings from Joliffe and Baron-Cohen (1997) which showed individuals with autism and Asperger's syndrome were just as likely to begin drawing the global outline first. These findings seem to be detrimental to the theory of WCC as no local bias was found. However, the theory of Hierarchisation which predicts no preferences for either the local or global level might be able to account for these results.

Use of representation in drawings was also similar in the autistic and non-autistic groups. The fact that there was minimal use of representation in all groups however may indicate that the task was not ideal for evoking meaningful interpretation. Joliffe and Baron-Cohen (1997) did find that individuals without autism were likely to give meaning to abstract stimuli in the adult embedded figures test. However, they were directly asked to describe the figure for 15 seconds, unlike in the Rey figure test where I never explicitly asked the individual to reflect on the appearance of the shape. If this had been done, I might have found a greater number of those without autism using representations in their drawings.

On the Rey recognition task those with autism and Asperger's syndrome performed similarly to comparison groups on their recall of global and local designs. Therefore, those in the autistic population were no better at recognising local and no worse in recognising the global designs of the Rey figure. This offers little support for the theory of weak central coherence. Again, this would not undermine the theory of Hierarchisation which predicts that global and local details are processed equally well.

Developmental trends

Individuals with typical development aged 11 did significantly better than those at age 7 on the embedded figures and block design test. This shows an increase in visuo-spatial ability with age. A similar developmental trend between these typically developing groups was also observed on the Rey copy and recall trials, but this did not reach significance.

Results and discussion of correlations

Only data from subjects who completed all the tests were included in the correlational analyses. There were three main questions I wanted to explore. Firstly, I wanted to know whether performance on the 4 illusions correlated. Secondly, I wanted to know whether the tasks associated with WCC correlated with one another. Finally, and most importantly, I wanted to see if performance on the block design, embedded figures, and Rey figure test predicts susceptibility to illusions. The results are discussed in the following section in relation to these specific questions.

1.) Do the illusions correlate with one another?

Each participant's mean score on the control trials was subtracted from their mean score on the illusion trials to yield a difference score. The data were combined across groups on all four illusions (Ponzo, Hat, Muller-Lyer, Titchener) and entered into a correlational matrix (see Table 4:11 for results). A Bonferroni correction was applied. This was done by dividing .05 by the number of comparisons being made (6) which resulted in a significance level of .008. With the Bonferroni correction there were no significant correlations. Overall, the analyses did not show any relationships between performances on the four illusions. However, this does not exclude the possibility that one or more of the illusions may be related to performance on the embedded figures, block design, or Rey figure test. I will return to this question later on in this section.

Table 4:11

Correlation coefficients and significance levels showing the relationship between the four illusions

Degrees of freedom equals 77 for all below.

Hat	Ponzo	Muller-Lyer	Titchener	
XXXXXX	r =.23, p <.05	r = -.25, p <.05	r =.01, p =.935	Hat
	XXXXXX	r = -.13, p =.262	r = -.11, p =.352	Ponzo
		XXXXXX	r =.03, p =.774	Muller-Lyer
			XXXXXX	Titchener

2.) Do the embedded figures, block design, and Rey figures test correlate with one another?

All factors (embedded figures, block design, Rey copy, Rey recall, Rey recognition) correlated when all groups were combined. To be certain these correlations were reliable a Bonferroni correction of .005 was applied [.05 divided by number of comparisons (10)]. These results are displayed in Table 4:12.

Table 4:12

Correlation coefficients and significance levels showing the relationship between the visuo-spatial tasks

* Indicates significance when a Bonferroni correction of .005 was applied.
Degrees of freedom equal 77 for all below.

Embedded figures	Block design	Rey copy	Rey recall	Rey recognition	
XXXX	*r = -.81, p<.001	*r = -.68, p<.001	*r = -.49, p =<.001	*r = -.46, p <.001	Embedded figures
	XXXX	*r = .72, p <.001	*r = .57, p=<.001	*r = .39, p <.001	Block design
		XXXX	*r = .71, p< .001	*r = .53, p <.001	Rey copy
			XXXX	*r = .37, p <.005	Rey recall
				XXXX	Rey recognition

Although I have established that these tasks are related, the association may be due to a factor such as VMA rather than WCC. For instance, all the tests place a demand on verbal comprehension skills in order to understand the instructions. Those who are poor at comprehending would be disadvantaged on all tasks. When VMA was partialled out all correlations remained between embedded figures, block design, Rey copy, and Rey recall (see Table 4:13). This suggests that these tests are related independently of VMA. Two correlations did not remain significant at the p< .05

level when VMA was partialled out. These were between the Rey recognition test and both the block design task and Rey recall trial.

Table 4:13

Correlation coefficients and significance levels showing the relationship between the visuo-spatial tasks with VMA partialled out

EFT	BDT	Rey copy	Rey recall	Rey recognition	
XXXX	*r = -.76, p<.001	*r = -.57, p<.001	*r = -.37, p< .005	*r = -.26, p< .05	EFT
	XXXX	*r = .63, p<.001	*r = .48, p< .001	r = .20, p=.087	BDT
		XXXX	*r = .65, p< .001	*r = .34, p< .005	Rey copy
			XXXX	r = .21, p=.069	Rey recall
				XXXX	Rey recognition

It can be concluded that the embedded figures, block design, Rey copy, and Rey recall trials are strongly associated. They are also related independently of VMA. Accordingly, it is reasonable to suppose that they all measure WCC. On the other hand, perhaps the recognition task does not involve coherence ability to the same extent as the other tasks. It does not require an individual to actively integrate or analyse visual information in the same way. That is they do not need to visually manipulate the stimuli, they merely need to recognise it. Therefore, from this point on I will not consider the Rey recognition test in the analyses since the tests associated with WCC (i.e. visuo-spatial tasks) are the primary focus of this study.

Each group was examined independently to see if the significant correlations that emerged in the combined data remained significant. A Bonferroni correction was not applied here as these sub-analyses were begun with the assumption that it would be inappropriate to use a conservative criterion of significance. Since the Rey recognition task was not strongly correlated with the other measures in our previous analysis it was not considered here. Overall, there seemed to be strong relationships between performances on many of the tasks as can be seen from Table 4:14. Many of these significant correlations persist throughout all groups such as block design and embedded figures, block design and Rey copy, and Rey copy and Rey recall. Since these tasks inter-correlate fairly well, they will be accepted as a measure of central coherence.

Table 4:14

Results of correlations on visuo-spatial tasks for each group separately

Note: Table shows correlational coefficient and degrees of freedom.
* Indicates significance at the .05 level.
* * Indicates significance at the .01 level.
n.s. Indicates not significant

Group	Autistic	Asperger's	MLD	Year 3	Year 6
BDT & EFT	-.72**(13)	-.85**(8)	-.79**(17)	-.56*(15)	-.71** (16)
BDT & Rey copy	.53*(13)	.91**(8)	.77**(17)	.58*(15)	.66**(16)
BDT & Rey recall	.26 n.s.(13)	.91**(8)	.51*(17)	.52*(15)	.64**(16)
Rey copy & Rey recall	.53*(13)	.76*(8)	.83**(17)	.51*(15)	.75**(16)
EFT & Rey copy	-.74**(13)	-.92**(8)	-.63**(17)	-.11 n.s.(15)	-.53*(16)
EFT & Rey recall	-.46 n.s.(13)	-.70*(8)	-.45 n.s.(17)	.14 n.s.(15)	-.41 n.s.(16)

3.) Is there a relationship between good performance on the embedded figures test, block design test, Rey complex figures test and non-susceptibility to illusions?

Correlation results

A difference score was calculated for each illusion by subtracting each participant's mean on the control trials from their mean illusion score. Data were combined from all groups and correlation analyses were carried out to see if there were relationships between any of the visuo-spatial tasks and the illusions. A Bonferroni Correction of .001 was applied to our analyses [.05 divided by the number of comparisons (36)]. The results showed that the Muller-Lyer illusion correlates most strongly with performance on visuo-spatial tasks. The Muller-Lyer significantly correlated with the embedded figures test (r=.48, df=77, p<.001), block design test (r= -.46, df=77, p <.001), Rey copy test (r= -.45, df=77, p <.001), Rey recall (r= -.41, df=77, p <.001), and the Rey recognition test (r= -.37, df=77, p =.001). The results also showed a significant correlation between the Hat illusion the Rey copy test (r= .40, df=77, p <.001). These correlations will be the primary focus of our further analyses which look at each group independently.

Individual group results

Table 4:15 shows the results of the correlational analyses for each group separately. It seems that in general the association between the Muller-Lyer and the other tests is more evident in year 6 than in any other groups. The relationship is positive between the embedded figures test and the Muller-Lyer illusion since those with a lower mean completion time (performed well) had a lower mean difference score on the Muller–Lyer illusion (indicating less susceptibility). This same relationship was also found to be significant for the MLD group. There was a negative relationship between the Muller-Lyer and the block design test, Rey copy, and Rey recall tests. Thus, those who achieved higher scores on these tasks had lower difference scores on the illusion. In other words, those who performed well on these tasks were less susceptible to the Muller-Lyer illusion. In the MLD group a similar relationship was found between the Muller-Lyer and the BDT, but not with the other tasks. In general there is some evidence to suggest that good performance on these tests is associated with less susceptibility to the Muller-Lyer illusion. Another significant relationship was between the Hat illusion and Rey copy trial for the autistic group only. This finding shows something quite different than the results with the Muller-Lyer illusion. It seems those who obtained a higher score on the Rey copy test had a higher mean difference score on the Hat illusion. Therefore, those who were strongly susceptible to the Hat illusion achieved more points for copying the Rey figure. A partial correlation was also carried out to establish whether these relationships remained if VMA was accounted for. The results showed that the correlations remained significant (see Table 4:16).

Table 4:15

Results of correlations between visuo-spatial tasks and the Hat and Muller-Lyer illusions for each group

* Indicates significance at the .05 level.

* Indicates significance at the .01 level

Group	EFT	BDT	Rey copy	Rey recall	Rey recognition
Autistic	-	-	Hat (.66)**	-	-
Asperger	-	-	-	-	-
MLD	Muller-Lyer (.55)*	Muller-Lyer (-.50)*	-	-	-
Year 3	-	-	-	-	-
Year 6	Muller-Lyer (.74)**	Muller-Lyer (-.73)**	Muller-Lyer (-.54)*	Muller-Lyer (-.62)**	-

Table 4:16

Results of correlations between visuo-spatial tasks and the Hat and Muller-Lyer illusions for each group with VMA partialled out

Group	EFT	BDT	Rey copy	Rey recall	Rey recognition
Autistic	-	-	Hat (.67)**	-	-
Asperger	-	-	-	-	-
MLD	Muller-Lyer (.59)**	Muller-Lyer (-.56)*	-	-	-
Year 3	-	-	-	-	-
Year 6	Muller-Lyer (.77)**	Muller-Lyer (-.74)**	Muller-Lyer (-.56)*	Muller-Lyer (-.62)**	-

Multiple regressions

I wanted to know if performance on tasks associated with WCC predicts susceptibility to illusions. Therefore, a multiple regression was carried out using the embedded figures test, block design, Rey copy, and Rey recall as predictors of performance on the illusions. This was done on the combined data of all the groups. The Rey recognition trial was not included as it did not correlate strongly with the other tasks. If non-susceptibility to illusions is related to WCC, like Happe argues, then one would expect a significant outcome. A regression was carried out for each of the illusions individually using the same four tasks as predictors. The results indicated that performance on the tasks significantly predicted performance on the Hat illusion F=3,87(4,78), p<.01 and Muller-Lyer F=6.95 (4,78), p<.001. Good performance on the visuo-spatial tasks predicted an individual would be more susceptible to the Hat illusion, but less susceptible to the Muller-Lyer illusion. Performance on the tasks did not significantly predict susceptibility to the Ponzo and Titchener illusions.

I wanted to know whether this pattern of results would be found in each group separately, or whether it was evident only in particular populations. The autistic and Asperger's group were combined since individually the group populations would have been too small. It was expected that both these groups would perform well on measures of WCC so this should not be a problem. The results indicated that performance on the embedded figures, block design, Rey copy and Rey recall tasks significantly predicted how the autistic/Asperger's group did on the Hat and Titchener illusion (see Table 4:17). In general, those with autism and Asperger's syndrome who did well on visuo-spatial tasks were more susceptible to the Titchener illusion. This contradicts Happe's predictions that weak coherence results in less susceptibility to illusions. In regards to the Hat illusion, good performance on the visuo-spatial tasks predicted an individual would be more susceptible to the illusion. This again is not in line with Happe's argument. In fact the only evidence that weak coherence, as measured by the visuo-spatial tasks, predicted less susceptibility to illusions was in a non-autistic group. Those in year 6 who performed particularly well on visuo-spatial tasks were less susceptible to the Muller-Lyer illusion. This is somewhat ironic as Happe argued that the Muller-Lyer illusion was not the best for tapping coherence ability as the stimulus was a single unitary figure. Yet this illusion was not only the most strongly related to visuo-spatial tasks, but the relationship was in the appropriate direction. Generally, the results indicate that tasks associated with WCC do not strongly predict performance on the illusions.

Table 4:17

Results of multiple regression analyses using the visuo-spatial battery as a predictor for performance on illusions

Group	Hat	Ponzo	Muller	Titchener
Autistic/ Asperger	* $F = 3.36, p<.05$	$F = 1.01, p=.424$	$F = .33, p=.852$	* $F = 2.91, p<.05$
MLD	$F=.80, p=.544$	$F= .98, p=.448$	$F= 2.25, p=.116$	$F = .65, p=.635$
Year 3	$F=.67, p=.624$	$F= 1.63, p=.231$	$F= 1.34, p=.311$	$F= .80, p=.548$
Year 6	$F=.54, p=.710$	$F = .39, p=.816$	* $F= 7.40, p<.005$	$F = 2.41, p=.102$

General Discussion

Overall these results question the strength of Happe's argument that individuals with autism do not succumb to illusions because of a weak drive for central coherence. As I already said in the interim discussion there was little evidence of any group differences in perception of visual illusions. Those with autism must be capable of a certain level of coherence if they do succumb to the illusions. However, it could be that illusions are not tapping coherence ability at all. Happe argues that illusions would involve low level coherence because one needs to perceptually integrate elements in order to perceive the illusory effects. If coherence were the underlying operating mechanism, one would expect some relationship between how an individual performs on one illusion and how they perform on another. The fact that no correlations were found between the illusions suggests that they may be working on other perceptual mechanisms rather than coherence alone (e.g. depth cues or framing effects). Moreover, performance on visuo-spatial tasks did not predict susceptibility to all four illusions for every group.

It could be that the mechanisms involved in coherence (drawing together pieces to perceive a whole) are less apparent in those illusions where performance was not significantly predicted by the visuo-spatial battery. Surprisingly however, this does not seem to be the case. As discussed earlier, in the Ponzo and Titchener illusions the inducing context is very evident and separable from the induced elements. Thus, if a person could easily separate context from individual elements on tasks such as the embedded figures and block design test, then one might expect them to be less susceptible to the illusions. They should find it easy to ignore the context which surrounds the shapes they were required to match in size. Yet it was on these illusions where performance was not significantly predicted by the battery of tests. The illusion that most strongly correlated with performance on the battery of was the Muller-Lyer illusion (in the MLD and year 6 groups only). However, this illusion was argued by Happe (1996) to not be ideal for testing coherence as the parts were connected forming a whole. She said this illusion could not be easily separated into "inducing context" and "induced figure". Performance on the Hat illusion, which was also a unitary figure, significantly correlated with the Rey copy test. However, this was not in the direction that Happe would have predicted. Individuals who performed very well on the Rey copy test were more susceptible to the Hat illusion. Altogether, this evidence offers little support for Happe's argument.

Performance on the embedded figures test, block design, and Rey copy test significantly correlated as would be expected given that all have been argued to test visuo-spatial ability. Previous research has argued that good performance on the embedded figures test and block design test suggest an individual may display "weak coherence"(Shah and Frith, 1993; Frith, 1989). The fact that individuals with autism performed better than their mental aged matched controls (MLD group) on all three of these tests suggest that those with autism may be superior on all visuo-spatial tasks. This idea has been suggested by Baron-Cohen and Joliffe (1997). It could be that having a cognitive style such as "weak coherence" is advantageous to an individual on all visuo-spatial tasks. However, we could not say such a cognitive style causes an individual to be less susceptible to illusions.

CHAPTER FIVE

Cognitive styles: Do individuals with autism and Asperger's syndrome rely on meaningful context or visual information?

The experiments in this chapter form the basis of a paper by Ropar and Mitchell, "Do individuals with autism and Asperger's syndrome utilise background knowledge in pairing visually presented stimuli?", that is under submission with the Journal of Autism and Developmental Disorders.

5:1 Background Knowledge

In our previous chapters I established that coherence is intact at lower perceptual levels in autism. Individuals with autism are able to integrate lines and shapes as evidenced by their susceptibility to illusions. It appears that difficulties "drawing together pieces of information to create a meaningful whole" may be restricted to higher levels of processing. In chapter four I found that those with autism were better than verbal mental matched controls on the embedded figures, block design, and Rey copy trial. This shows evidence of weak coherence at a visuo-spatial constructional level as specified by Happe (1999). One might assume that individuals with autism would also have difficulties with coherence at levels higher than the visuo-spatial constructional level. However, this assumption might be premature given the inconsistent findings from studies of comprehension and use of meaningful information in autism.

By meaningful information I are referring to semantic as well as conceptual knowledge that has been acquired through experience. Bartlett (1932) argued that any new information we are presented with is always related to the pre-existing background knowledge he called schemata. Therefore, it follows that information is easier to retrieve if it is related to the knowledge schema being used at the time. Evidence for this comes from Palmer (1975) who found that individuals (without autism) were better at recalling objects when presented in a scene having an appropriate context as opposed to an inappropriate context. According to Frith's account of weak central coherence we would not expect individuals with autism to be affected by "context". Their failure to attend to contextual information would neither assist nor hinder performance on the task.

Before I continue it may be useful to make a distinction between "context" and "background" or "meaningful" information. "Context" as Frith uses the term, can be either meaningful or non-meaningful. An example of "non-meaningful context" would be with visual illusions (e.g. circles). We can see an example of "meaningful context" on the embedded figures test (e.g. pram). This chapter is concerned with coherence at higher-levels involving only "meaningful context". Therefore, I will use the terms "background knowledge" or "meaningful information" to specify the type of context that is being investigated.

5:2 The Salience of Meaning

Experimental studies suggest that individuals with autism do neglect meaningful information. I have already mentioned how individuals with autism give the incorrect yet more common pronunciation of ambiguous homographs (Frith & Snowling, 1983). Individuals with autism also fail to use the meaning of thematically related words to assist recall (Tager-Flusberg, 1991). However, in a second experiment where individuals with autism were presented with a cued-recall test they were able to utilise background knowledge to facilitate recall. This suggests that although those with autism are capable of processing meaningful information, they simply do not choose to use it when performing a task. It does not appear to "pop out" to them in the way that it does to individuals without autism. It could be that what is salient to an individual with typical development, is not salient to those with autism. Frith (1989) argues that peculiar patterns of attention in autism can be explained by a deficit in the central thought processes. We are inclined to focus on those aspects of a picture or story which are most meaningful to us. According to WCC those with autism may not share this same "drive for meaning", or rather other features of stimuli may be more meaningful to a person with autism. Boucart and Humphreys (1992) argue that global processing is closely related to higher level processes such as semantic knowledge. They found that on a similarity judgement task that individuals with typical development could not process global shape without accessing semantic information. Thus, if an individual prefers to process information at the global level, semantic information might be more salient to them than if an individual attended to the local level as we would expect to find in autism.

Another line of argument which is somewhat related to WCC has been suggested by Snyder and Thomas (1997). They suggest that autistic savants do not impose visual or linguistic schema on what they are drawing. This follows from Snyder and Barlow's (1988) view that what we perceive in our visual field conforms to certain patterns. Our perception can be more efficient if we have certain expectations of what we are to see. They argue that typically developing individuals have mental representations that pick up on the salient or ecologically significant aspects in the environment.

Evidence of these internalised representations can be seen in young children's drawings in such that they draw what they conceptually know rather than what they actually see (Lee, 1989). Snyder and Thomas (1997) suggest that these fixed mental representations are absent in autistic children allowing them to draw more precisely. One example they provide is that of Nadia (Selfe, 1977). As a young child with little linguistic ability she could create outstanding drawings which were very realistic. However, as she grew older her language skills improved and her artistic ability deteriorated. In conclusion, they argue that savant abilities arise from the inability to apply linguistic or mental schema.

5:3 Savant abilities

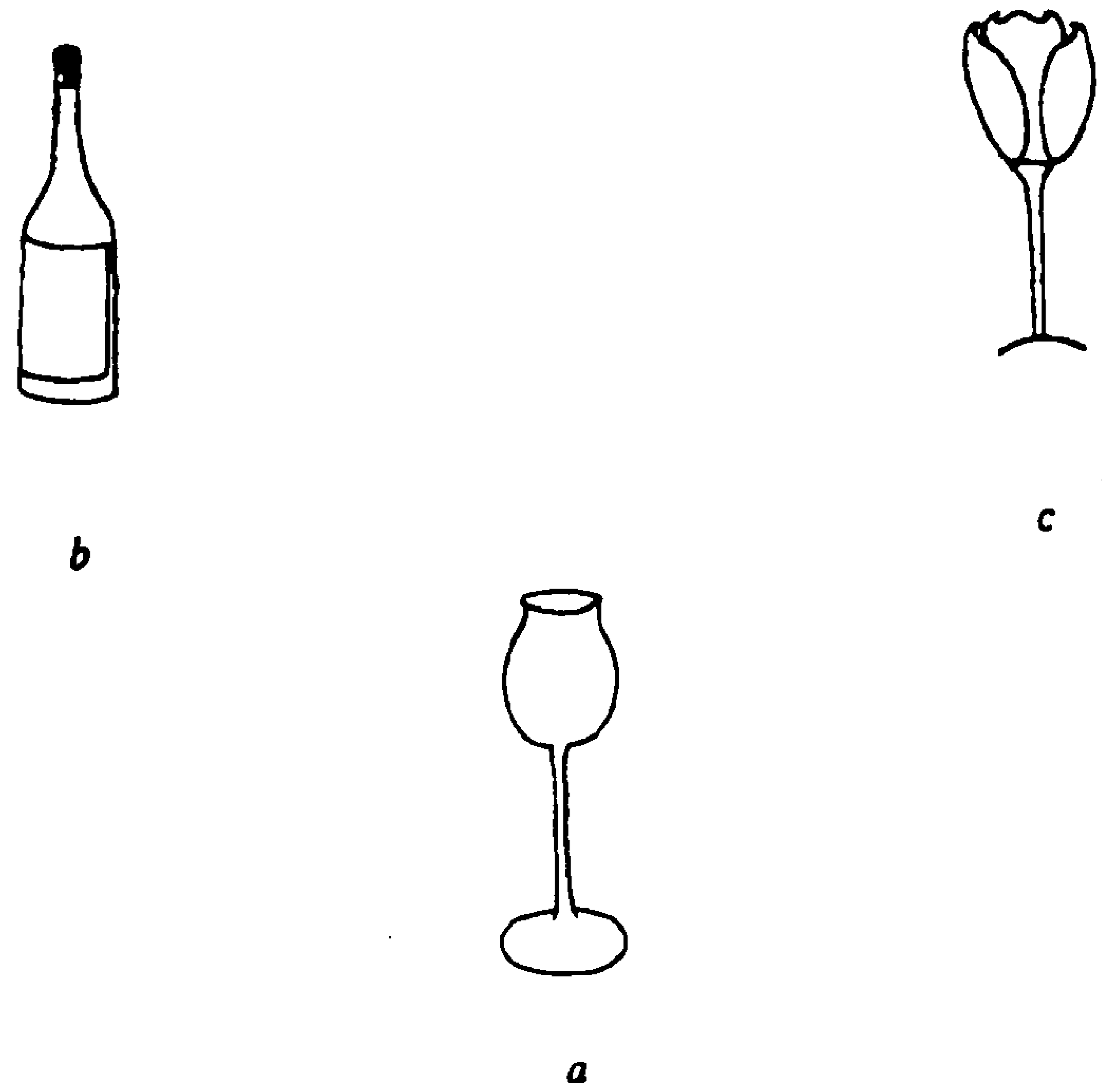
As described in Chapter 4, a study by Pring, Hermelin, and Heavey (1995) supported the claim that individuals with autism fail to use meaningful information in visual processing. An aim of their study was to investigate whether a cognitive style such as weak central coherence, as found in those with autism (Shah & Frith 1983;1993), might also exist in typically developing individuals who were artistically talented. They argued that artistic production requires an individual to decompose a picture into its basic elements (shape, colour, light) in order to recreate the pattern veridically. A preference to attend to the individual visual components of a picture rather than the meaningful whole might thus be found in artistically talented individuals as well as those with autism. Pring et al. (1995) tested artistically gifted as well as non-gifted individuals with normal development and with autism, yielding four participant groups. Participants were presented with a picture puzzle task and the block design test. Both require participants to recreate a pattern using individual blocks. The picture puzzle task depicted a meaningful scene (Winnie the Pooh) rather than an abstract pattern. While a global processing style could actually hinder one's ability to perform well in block design (Shah & Frith, 1993), performance could be enhanced by utilizing the meaningful information in the picture puzzle task.

On the block design task in the non-gifted groups, those with autism were significantly better than individuals with typical development. On the picture puzzle task, the two groups performed at the same level. Pring, et al. (1995) argued that the improved performance in those with typical development on the picture puzzle task, was due to their ability to make use of the meaningful information presented on the stimuli. In comparison, those with autism performed equally well whether or not it was possible to make use of the background information. There was also evidence that the autistic savant artists failed to benefit from meaning in the picture puzzle task, unlike the artistically talented comparison group. Pring et al. (1995) suggested that the performance of the clinical and comparison groups on the picture puzzle task was probably achieved via different routes. Those without autism seemed to use a semantic strategy, while those with autism may have employed a segmentation-based strategy as evidenced by their superior performance on the block design test.

Surprisingly, an earlier study by Pring and Hermelin (1993) failed to demonstrate a difference between those with and without autism in their use of meaningful information. They hypothesized that individuals without autism might pair a wineglass with a wine bottle due to the common semantic property that both are receptacles for wine (see Figure 5:1). In contrast, perhaps individuals with autism would pair a wineglass with a tulip due to the common structural property of gobletoid shape; no background knowledge would be required in order to note that the objects were structurally similar. However, Pring and Hermelin were surprised to find that their sample of savant artists, some of whom had autism, were just as likely as comparison participants to sort according to semantic properties. They concluded that savant artists are influenced by background knowledge to the same extent as artistically talented normal individuals. This evidence appears to contradict the claim that autistic individuals experience 'less capture by meaning' (pace Shah & Frith, 1983).

Figure 5:1

Example of stimuli used in Pring and Hermelin's study (1993)



5:4 Introduction

Pring and Hermelin's (1993) findings generate several questions. First, their study was confined to testing savant artists. This was entirely appropriate given that their hypothesis explicitly concerned the link between artistic skills and categorisation. It remains uncertain, however, whether a more typical population of individuals diagnosed with autism or even Asperger's syndrome would also choose to categorise semantically. It can be predicted from the hypothesis of 'less capture by meaning' that they would not be influenced by background knowledge and instead would prefer to categorise according to surface properties of the presented stimuli.

A further consideration concerns how structural similarity is defined. Whilst a wineglass and tulip appear structurally similar to those of us without autism, perhaps those with autism would attend to subtle differences. There are many clinical reports of autistic individuals having heightened sensitivity to fine detail in their environment. For example, one child found small objects on a patterned carpet more rapidly than an individual with typical development (Frith & Baron-Cohen, 1987). This has been attributed to keen attention and memory for detail. Further evidence comes from a perceptual discrimination study which suggests that individuals with autism have difficulty processing common features but are relatively good at processing unique features (Plaisted, O'Riordan, & Baron-Cohen, 1998a). This attention to a small detail of the picture in Pring and Hermelin's study would prevent an individual matching visually. Some studies (Mottron & Belleville 1993;1995) have reported that individuals with autism, unlike those without autism, begin drawing a picture by details rather than the global outline. Authors of these studies argue that the global shape has less impact on those with autism. In order to perceive structural similarity between two stimuli in Pring and Heremlin's study one would need to attend to the global outline.

In order to investigate the role of background knowledge in visual processing, I devised a test that effectively gave participants the choice to pair objects according to surface detail or deeper semantic properties. Participants were shown a sequence of pictures of coloured objects. Some had an associated colour (e.g. a banana), but were coloured atypically (blue). Others did not have a specific associated colour (e.g. a car) and were coloured ad hoc (red). Two patches of colour were presented alongside, such as yellow and blue for the banana and red and green for the car. Using the wording formulated by Pring and Hermelin (1993), participants in our study were invited to select which colour goes best with the target picture. In the case of a banana, would participants be influenced by background knowledge, as indicated by choosing the semantically appropriate yellow? Alternatively, would they base their choice on the surface property by selecting blue? Any fixation on minute detail would not stand in the way of a surface-based approach in this task, because the blue of the object picture and the blue of the colour patch were identical. Furthermore, since the whole object on each card was coloured, a person focusing only on one part of the picture could still choose the visually matching colour patch. Hence, this ought to be a more sensitive test, than Pring and Hermelin's, for identifying population differences in the preference to pair according to surface property.

Obviously, the wording of the question in a task like this is critical in influencing participants either to pair according to background knowledge or according to surface properties (cf. Carlson, 1977; Lichte & Borresen, 1967). As with Pring and Hermelin (1993), our aim was to ask a suitably ambiguous question to allow participants either to select colour according to background associations or according to surface properties. Importantly, if participants with autism were not inclined to pair according to background knowledge, there would be no pragmatic impediment to their pairing according to surface properties.

A further virtue of the design is that it would be able to establish whether participants were likely to use a surface-based strategy when the object in question lacks an associated colour (e.g. a car). If participants chose the surface colour for a picture of a car, but chose the associated colour for a banana, this would suggest that they are sensitive to which objects do and do not have an associated colour. Background knowledge would only influence their judgments when appropriate. Perhaps individuals with autism, unlike those with typical development, might make a surface-based selection whether or not the presented object has an associated colour. This would raise the possibility that they do not optimally utilise background knowledge. Alternatively, we might find that participants with autism judge differently between items that do and do not have an associated colour, but the size of the contrast between conditions might be less than in comparison groups. In other words, those with autism might be influenced by background knowledge, but only weakly.

Experiment 5:1

5:4 Method

Subjects. Table 5:1 summarises details of the participants. Eight individuals with autism and 10 with Asperger's syndrome participated in the study. All were diagnosed by experienced clinicians according to standard criteria (DSM-IIIR, 1987 or DSM IV, 1994). Verbal mental age was assessed using the British Picture Vocabulary Scale (BPVS: Dunn, Dunn, Whetton & Pintilie, 1982). They were compared with individuals with moderate learning difficulties and participants with typical development. Due to constraints on sample, the mean VMA of participants with moderate learning difficulties was slightly lower than that of participants with autism. If participants with autism performed the tasks differently from others, including those with moderate learning difficulties, it would seem appropriate to explain this specifically with reference to autism rather than more generally with reference to the associated learning difficulties.

Table 5:1

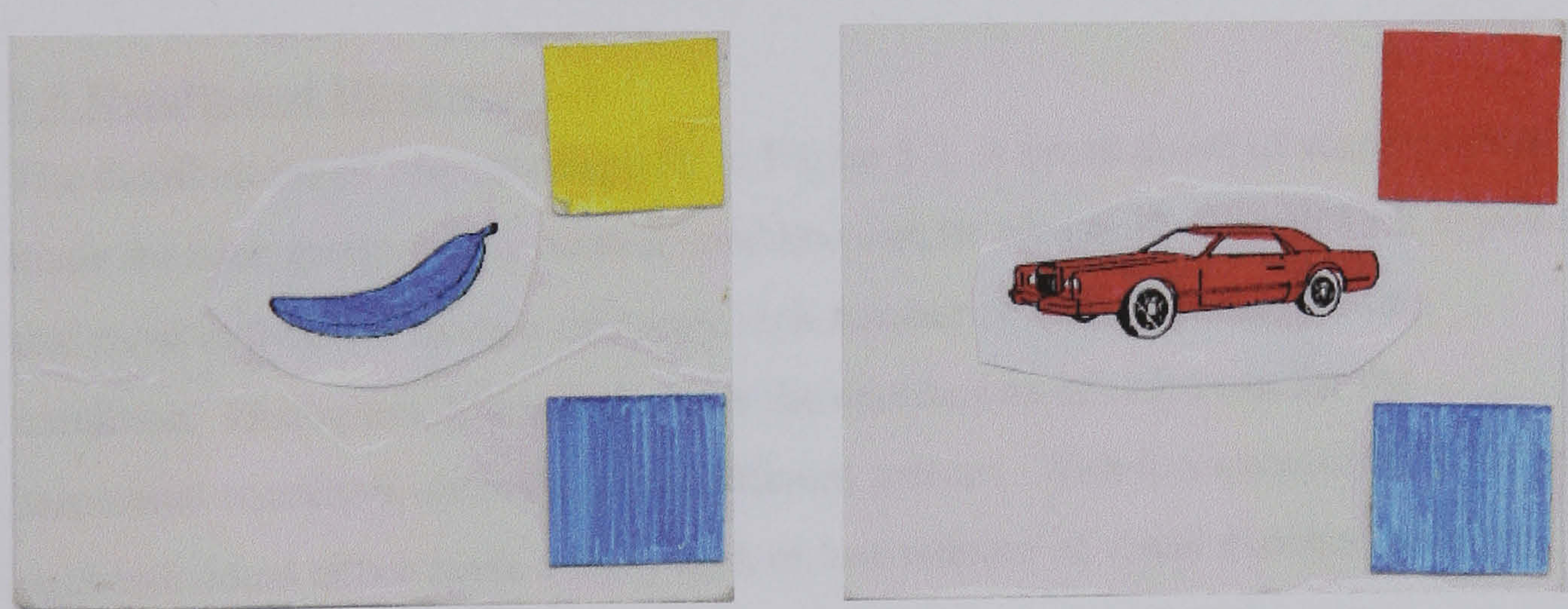
Subject characteristics for Experiment 5:1

Group	CA (y;m)	VMA(y;m)
Autistic (N=8)		
Mean	19;2	7;11
SD	9;3	2;6
Range	(12;9-39;10)	(4;9-12;0)
Asperger (N=10)		
Mean	19;8	13;1
SD	5;10	4;11
Range	(11;0-29;6)	(6;8-19;6)
MLD (N=22)		
Mean	10;8	5;11
SD	0;4	1;4
Range	(9;11-11;4)	(3;5-8;7)
Reception (N=20)		
Mean	5;3	
SD	0;3	
Range	(4;10-5;8)	
Year 3 (N=25)		
Mean	8;0	
SD	0;3	
Range	(7;7-8;6)	
Year 6 (N=20)		
Mean	11;0	
SD	0;5	
Range	(10;7-11;7)	

Stimuli. The materials included six 1x2 inch colour cards (blue, red, green, yellow, brown, orange). These were used in order to screen participants for the ability to name colours. The stimuli for the main part of the procedure included 24 white cards that were 4x5 inches in size. Each bore a centrally positioned picture that was approximately 1.5 to 2.5 inches in size. Twenty of the pictures were taken from Snodgrass and Vanderwart (1980). Two square patches of colour (1x1 in.) were situated on the right hand boarder of the card. One was aligned directly above the other in the right side corners. Twelve of the pictures showed objects that had a specific colour associated with them, but were coloured inappropriately (e.g. blue banana). Thus, the participant could match the object with the associated colour (yellow) or the presented surface colour (blue). The other 12 pictures did not have colour as a characteristic feature (neutral cards), and could be almost any colour, such as a red car. The colour choices for these included the same colour as the picture on the card (red) and an alternative colour (blue). The 6 colours used in the experiment were represented equally throughout the cards. Also, the positioning of the coloured patches was counterbalanced so that the visually matching patch appeared the same number of times on the top as on the bottom. Figure 5:2 illustrates an example card for each condition. For a complete list of the stimuli refer to Appendix 5:1.

Figure 5:2

Example of stimuli for Experiment 5:1



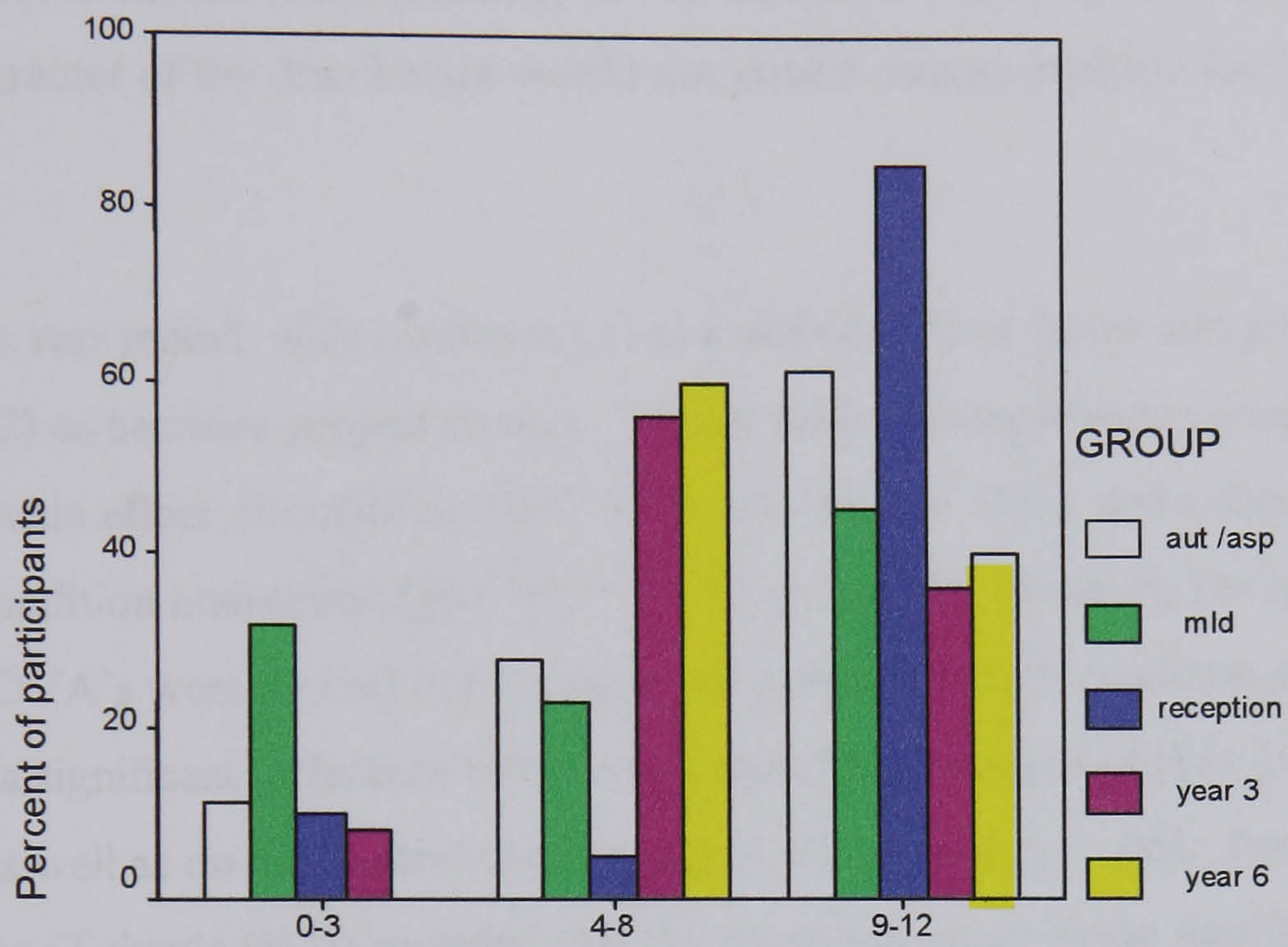
Procedure. To assess verbal mental ability the BPVS was administered to each of the clinical participants. Then subjects were shown 6 colour cards and asked to identify each of them. Those who correctly identified all 6 proceeded with the testing. Subsequently, each participant was presented with the 24 cards showing a picture and 2 colour choices. The experimenter pointed to the picture on each card and asked 'What's this?' If the participant could not correctly identify the picture they were told the correct answer. Participants proceeded to the next question whether they identified the picture correctly or were helped by the experimenter. Based on Pring and Hermelin (1993), each individual was then asked, "Which colour does the picture go best with?" They were asked to respond by pointing to one of the colour patches adjacent to the picture. The question was repeated for each of the 24 cards. Afterwards, individuals were asked to report the appropriate colour of the 12 items that had an associated colour. For example, they were asked 'What colour is a banana?' All 24 cards were randomly mixed together and then presented in the same order. The type of card presented first (semantic or neutral) alternated between participants.

5:5 Results and Discussion

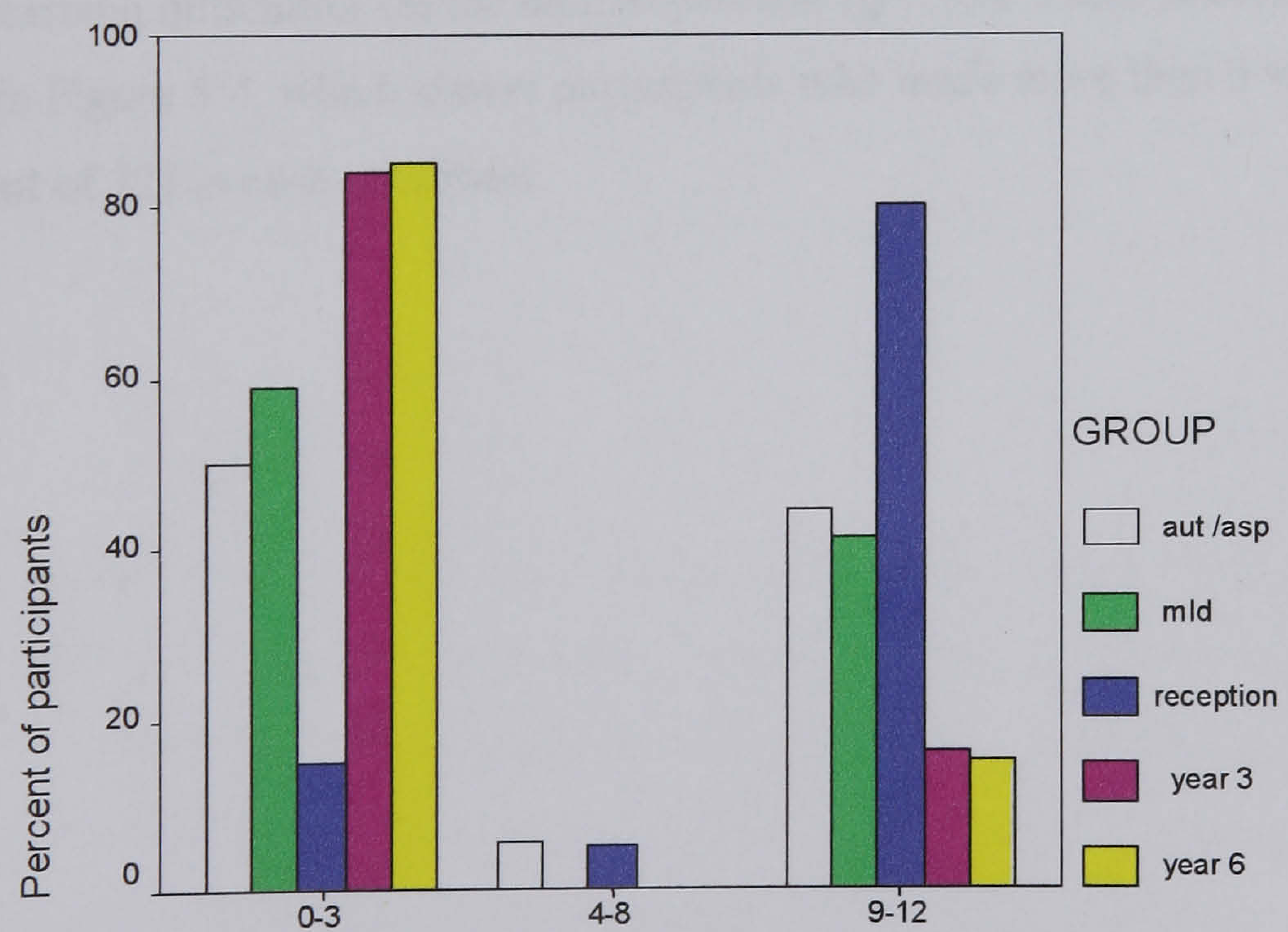
The distributions of responses appear in Figure 5:3. A break down of visual pairings made for each group on the neutral condition can be seen in Histogram 1. It appears that most individuals made a relatively high number of visual pairings for this condition. Histogram 2, which displays the distribution of responses for the associated condition, shows a rather different pattern. With few exceptions, it seems each individual either made a fairly high or low number of visual matches, resulting in a bimodal distribution. This suggests that on the associated cards, some individuals were influenced by background knowledge while some were not. Given there were relatively few participants with autism and Asperger's syndrome, we combined the data from both populations to form a single group for the purpose of analysis, unless stated otherwise.

Figure 5:3

Histograms showing distribution of responses on both conditions for Experiment 5:1



Histogram 1: Visual pairings on the neutral condition



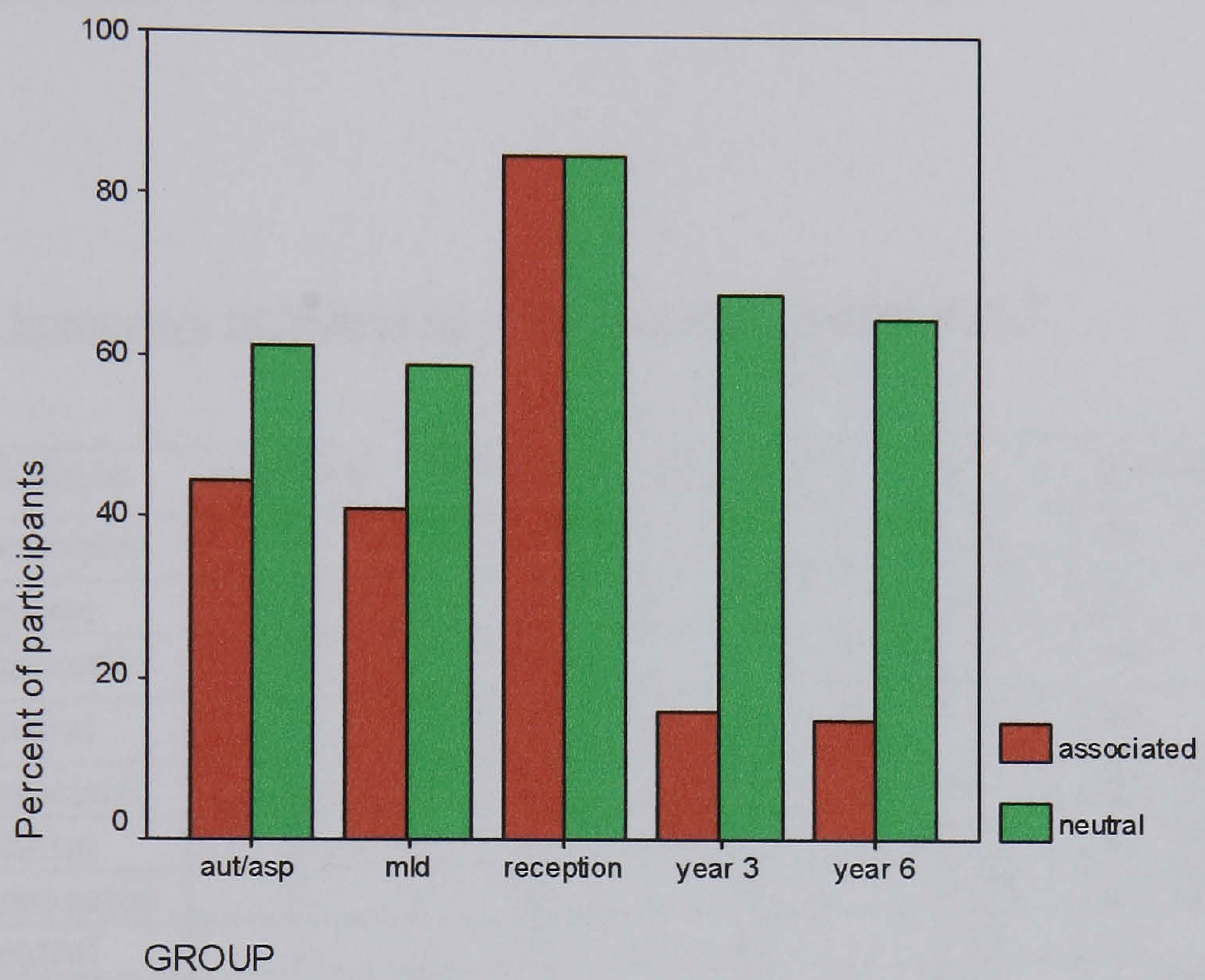
Histogram 2: Visual pairings on associated cards

Is the effect of background knowledge less potent in those with than without autism? An analysis of variance (ANOVA) was computed, given that nonparametric analyses are unsuitable for identifying an interaction effect. The ANOVA would remain stable even in the extreme case of a dichotomous dependent variable, so long as the data set is not too small (Lunney, 1970). Hence, it was assumed that the bimodal character of the distribution would not pose a serious problem for the ANOVA.

The analysis was mixed, with condition (2) as a within subject factor and group (5) and order (2) as between subject factors. Within subject comparisons revealed a significant main effect of condition [$F(1, 95) = 125.81$, $p < .001$], and a significant group by condition interaction [$F(4, 95) = 11.53$, $p < .001$]. To clarify the interaction, simple ANOVA's were carried out including all groups for each condition separately. There was a significant difference between groups on the associated [$F(4,104) = 9.21$, $p < .001$] as well as on the neutral condition [$F(4,104) = 2.71$, $p < .05$]. Post–hoc comparisons (Tukey's HSD) revealed that the reception group made significantly more visual matches than all other groups on the associated condition ($p < .05$ in all cases). Also, the reception group made significantly more visual matches than the moderate learning difficulties on the neutral pictures ($p < .05$). These differences are illustrated in Figure 5:4, which shows participants who made more than 6 visual pairings (out of 12) in each condition.

Figure 5:4

Percentage of participants preferring to pair visually on the associated and neutral conditions



A series of Wilcoxon signed ranks analyses were carried out to determine whether the difference between conditions was significant for each group independently. The results revealed that all groups, except reception, judged differently in the two conditions ($p < .05$).

Although participants with autism and Asperger's syndrome judged differently between conditions, perhaps in general they showed a visual preference. Seeing stimuli with an associated colour merely could have weakened a predominately visual preference. The number of individuals making more than 6 and fewer than 6 visual pairings was calculated for each group separately. If there was no preference within a particular group, then there should have been as many participants with a score above as below 6. The relevant frequency counts appear in Table 5:2. A significant majority of individuals in reception made more then 6 visual pairings on both the associated and neutral conditions. Year 6 was the only other group that showed a preference to pair visually, but this was specifically in the neutral condition. Year 3 and Year 6 both had significant majorities pairing non-visually in the associated condition.

Table 5:2

Frequency of individual responses for Experiment 5:1

Group	condition	exactly 6	below 6	above 6	χ^2	p value
autistic/ Asperger's	associated	0	10	8	0.11	ns
	neutral	2	5	11	1.56	ns
MLD	associated	0	13	9	0.41	ns
	neutral	0	9	13	0.41	ns
reception	associated	0	3	17	8.46	$p<.005$
	neutral	1	2	17	10.32	$p<.005$
year 3	associated	0	21	4	10.24	$p<.005$
	neutral	1	7	17	3.38	ns
Year 6	associated	0	17	3	8.46	$p<.005$
	neutral	6	1	13	8.64	$p<.005$

Note: "Above 6" and "below 6" refer to the number of visual pairings made. All the analyses in the above table have 1 degree of freedom and have been adjusted using Yate's correction for continuity.

Perhaps participants in reception classes did not judge differently between conditions because they were ignorant of the associated colour of the objects. In order to address this a 2 (condition) by 2 (group) mixed ANOVA was carried out excluding trials where errors on the post-test had been made. In the post-test, children were asked to name the colour of the objects appearing in the associated list. Since only the autistic/Asperger's and reception groups made errors on this part of the test, the following was conducted specifically with their data. The percentage of visual pairings made on all objects whose colour the child had identified correctly was calculated. There was a significant effect of condition [$F(1,36)=17.04$, $p<.001$], and a significant group by condition interaction [$F(1,36)=9.86$, $p<.01$]. The form of the interaction was the same as in the main analysis. There was also a main effect between groups [$F(1,36)=4.97$, $p<.05$], with reception children showing a stronger preference for visual pairing than those with autism/ Asperger's syndrome.

It is possible that individuals with autism and Asperger's syndrome performed differently from each other. In particular, perhaps only one subgroup judged differently between conditions. However, a Wilcoxon test confirmed a significant contrast in each subgroup independently: Autistic, $Z=2.07$, $p=.038$; Asperger's, $Z=2.38$, $p=.017$. Evidently, autism does not lead individuals to neglect background information when pairing a colour patch with the picture of an atypically coloured object. However, some individuals with autism/Apserger's syndrome did have a preference to match visually even in the associated condition, which is apparent in the bi-modal distribution in Figure 5:3. Since visual pairing was most common in the reception group, it raises the possibility that the tendency is linked with intellectual immaturity. Perhaps those with autism who did not judge differently between associated and neutral conditions were the less mature members of the group. If so, then VMA would predict the tendency to judge differently.

A stepwise multiple regression analysis was conducted using a forward inclusion procedure. The data were the score on the neutral condition, minus the score on the associated condition. This served as an index of the extent to which individuals judged differently between conditions. Considering participants with autism/Asperger's syndrome, CA was entered in the first step: $R^2=.06$. Diagnosis was entered on the second step (autistic/Asperger's): $R^2 = .39$, $F(1,15)=8.08$, $p< .05$. When VMA was entered in the third step, R^2 increased to .55, which reflected a significant change: $F(1,14)=4.80$, $p< .05$. In other words, VMA predicted the tendency to judge differently between associated and neutral conditions independently of CA and clinical diagnosis (autistic/Asperger's). A further regression was carried out entering these same predictors in a different order. As before CA was entered first as a predictor variable. When VMA was entered in the second step $\underline{R}^2$ increased to .50, indicating a significant change: $\underline{F}(1,15)=12.94$, $\underline{p}< .01$. Finally, diagnosis was entered, which increased $\underline{R}^2$ to .55. This increase was not significant which suggests that a difference in strategy choice between participants with autism and Asperger's syndrome is accounted for by the difference in VMA.

Would VMA also predict performance in the participants with MLD? Chronological age was entered in the first step ($\underline{R}^2=.04$). In the second step with VMA included, $\underline{R}^2$ increased to .33, which reflected a significant increase in the portion of 'explained' variance: $\underline{F}(1,19)=7.99$, $\underline{p}<.05$. Therefore, VMA significantly predicted selection strategy in all clinical groups.

The results show that most individuals, including those with autism and Asperger's syndrome, were influenced by background knowledge when pairing a colour patch with an atypically coloured object. The findings are consistent with Pring and Hermelin's (1993), showing semantically driven categorisation in the autistic population. Contrary to the suggestion of 'less capture by meaning', it seems individuals with autism and Asperger's syndrome are not distinguished by a tendency to focus on surface detail in this case.

Perhaps our procedure unwittingly primed individuals with autism to attend to their background knowledge of the associated colour of objects. Indeed, the fact that items were atypically coloured could have made them look peculiar, which may have led participants to reflect on the normal colour. Campbell and Olson (1990) suggest that the incongruity inherent in an atypically coloured object can act as a powerful cue to attend to the typical colour, and this seems to occur even in children as young as 3 or 4 years (Mitchell, Davidoff & Brown, 1996). In that case, it was expected that members of the reception sample in the present study, aged around 5 years, to judge differently between associated and neutral pictures. Because these children did not judge differently, it seems the typical colour did not inevitably impose itself on participants. In the context of failure to judge differently between conditions in the reception children, the success of participants with autism appears especially noteworthy.

Perhaps some factor linked with general intellectual maturity accounts for the ability to judge differently between associated and neutral pictures. This would explain why the younger individuals with typical development showed a weaker effect (or even no effect) compared with older individuals. It would also explain why VMA predicts performance in individuals with autism/Asperger's syndrome and individuals with MLD.

Nonetheless, it remains a possibility that a feature of the procedure primed individuals with autism to pair atypically coloured objects with their normal colour. According to Happe (1994a, 1999), weak central coherence, and by implication 'less capture by meaning', is connected with cognitive style rather than a deficit in processing information. She would not predict that the ability to be influenced by background information is missing, but that background information exerts less influence than in individuals without autism. Weeks and Hobson (1987) found evidence to support the idea of such a processing style in autism. They presented participants with photographs of individuals who differed in their sex, age, emotional expression, or the type of hat they were wearing. Those with autism were more likely than comparison participants to sort the photos by hat type than by facial expression. However, subsequent trials showed that some of the participants with autism were able to sort by facial expression when prompted. Presumably, this required more sophisticated processing of the stimuli, which is likely to involve integration of various facets of information. For example, what can we gather from the expression in the eyes and mouth in combination?

Perhaps the procedure inadvertently primed participants to consider background information in Experiment 5:1, albeit to an extent that was insufficient to elicit preference for the associated colour in reception children. Participants were asked to identify the picture on each card prior to pairing it with a colour. Naming the object might trigger attributes associated with it, such as the appropriate colour (Davidoff & Mitchell, 1993; Mitchell et al., 1996). This initial verbal identification may act as a prime to use a semantic strategy. Participants might have been more likely to select the visually matching colour if they had not been required to name the picture first.

A further study asking participants to name the object after they chose a colour would eliminate this possibility. A larger sample of individuals with autism and Asperger's syndrome would also be useful. If a weak preference for a visual strategy does exist, a larger clinical group would be more likely to reveal this. Also, it would allow us to assess more accurately whether visually-based pairing is more common in one or other of the autistic sub-populations.

Experiment 5:2

5:6 Method

Subjects. Similar population groups were tested in Experiment 5:2, though more individuals were included in the subgroups of participants with autism. None had participated in Experiment 5:1. Those with autism and Asperger's syndrome were diagnosed by clinicians according to standard criteria (DSM-IIIR, 1987 and DSM IV, 1994). The BPVS was used once again to determine verbal ability in the clinical populations (Dunn et al., 1982). Table 5:3 shows the subject characteristics for Experiment 5:2. The 21 individuals with autism were approximately matched for verbal mental ability with a group of 21 individuals with moderate learning difficulties. There were also 21 participants with Asperger's syndrome. Since typically developing children in year 3 and year 6 performed similarly in the previous experiment, only reception and year 3 participants were included in Experiment 5:2.

Procedure. The same stimuli from Experiment 5:1 were used in the current study. A similar procedure was used, except that subjects were asked to identify the objects after they had paired all 24 cards with a colour of their choice.

Table 5:3

Subject characteristics for Experiment 5:2

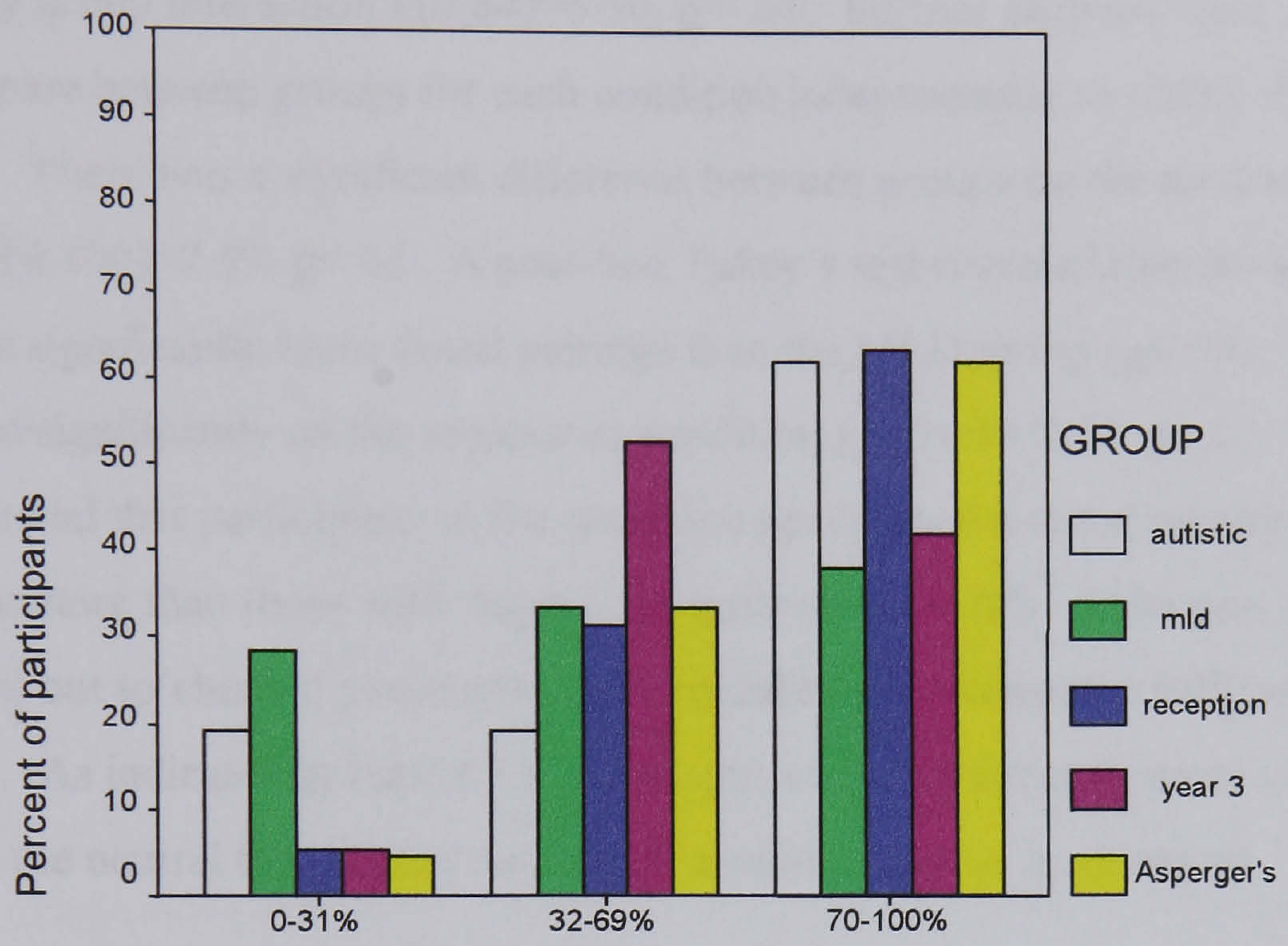
Group	CA (y;m)	VMA(y;m)
Autistic (N=21)		
Mean	12;11	8;10
SD	1;11	3;4
Range	(9;3-16;10)	(2;11-15;11)
Asperger's (N=21)		
Mean	13;2	12;3
SD	1;11	3;4
Range	(9;5-16;4)	(7;9-19;6)
MLD (N=21)		
Mean	13;2	7;8
SD	1;9	1;10
Range	(9;8-15;8)	(4;3-10;10)
Reception (N=19)		
Mean	5;8	
SD	0;2	
Range	(5;0 –5;6)	
Year 3 (N=19)		
Mean	8;3	
SD	0;3	
Range	(7;10-8;9)	

5:7 Results and Discussion

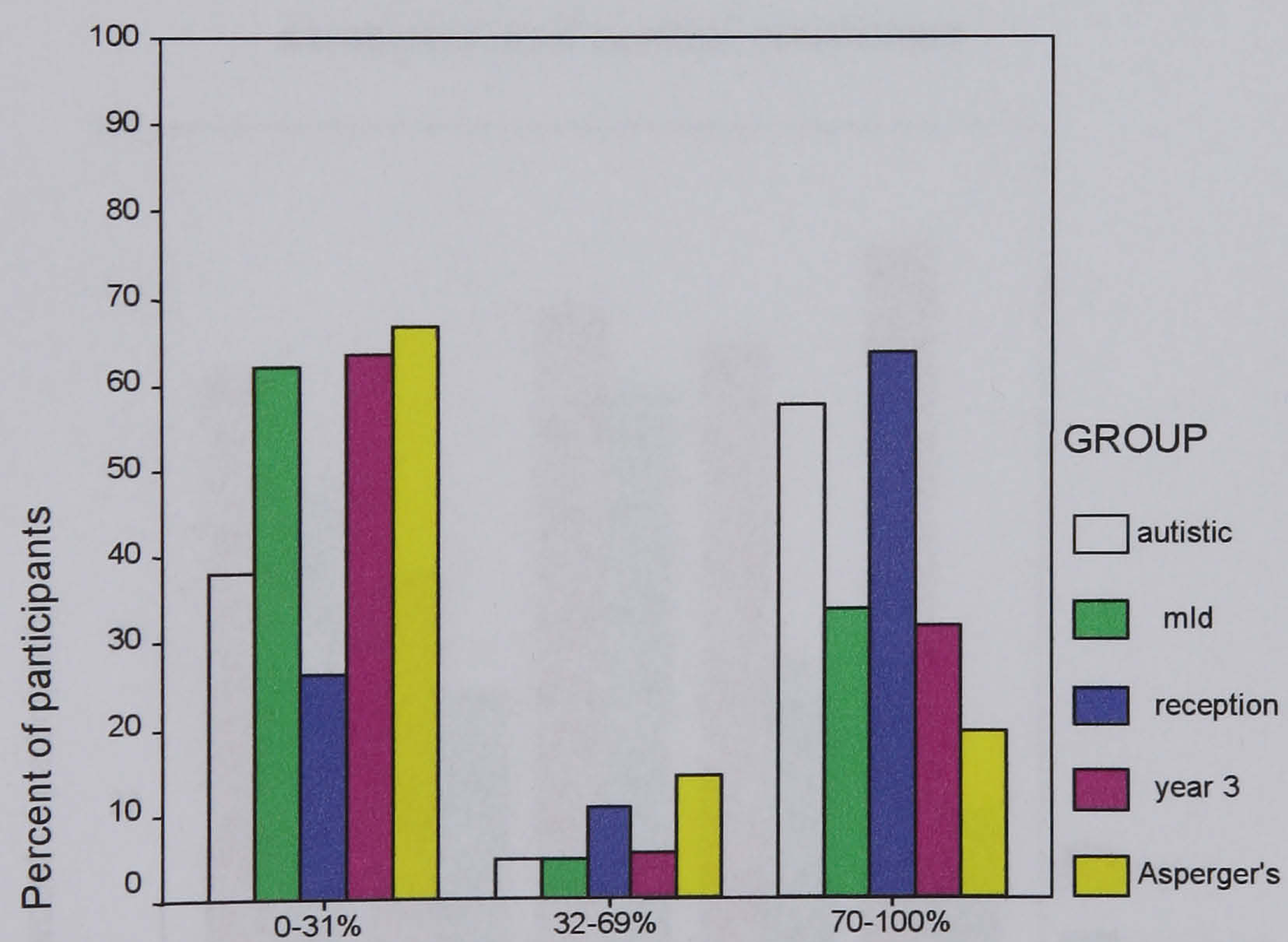
Unless stated otherwise, analyses were carried out on data from trials where a participant had subsequently identified the picture on the card. Two percentage scores were calculated for each participant. The scores represented the number of visual pairings out of the pictures identified correctly, with one score for the associated condition and the other for the neutral condition. Histograms (Figure 5:5) show that the distributions were similar to those in Experiment 5:1. On the neutral condition most individuals made visual pairings (Histogram 1). On the associated condition (Histogram 2) the responses were bimodally distributed, due to participants either making a fairly high or low number of visual pairings. As in Experiment 5:1, it seems background knowledge strongly influenced pairings in some individuals but not in others. Because it was difficult to recruit larger samples of participants with autism and Asperger's syndrome in Experiment 5:2, they were classified differently in the subsequent analyses unless stated otherwise.

Figure 5:5

Histograms showing distribution of responses on both conditions for Experiment 5:2



Histogram 1: Visual pairings on neutral cards

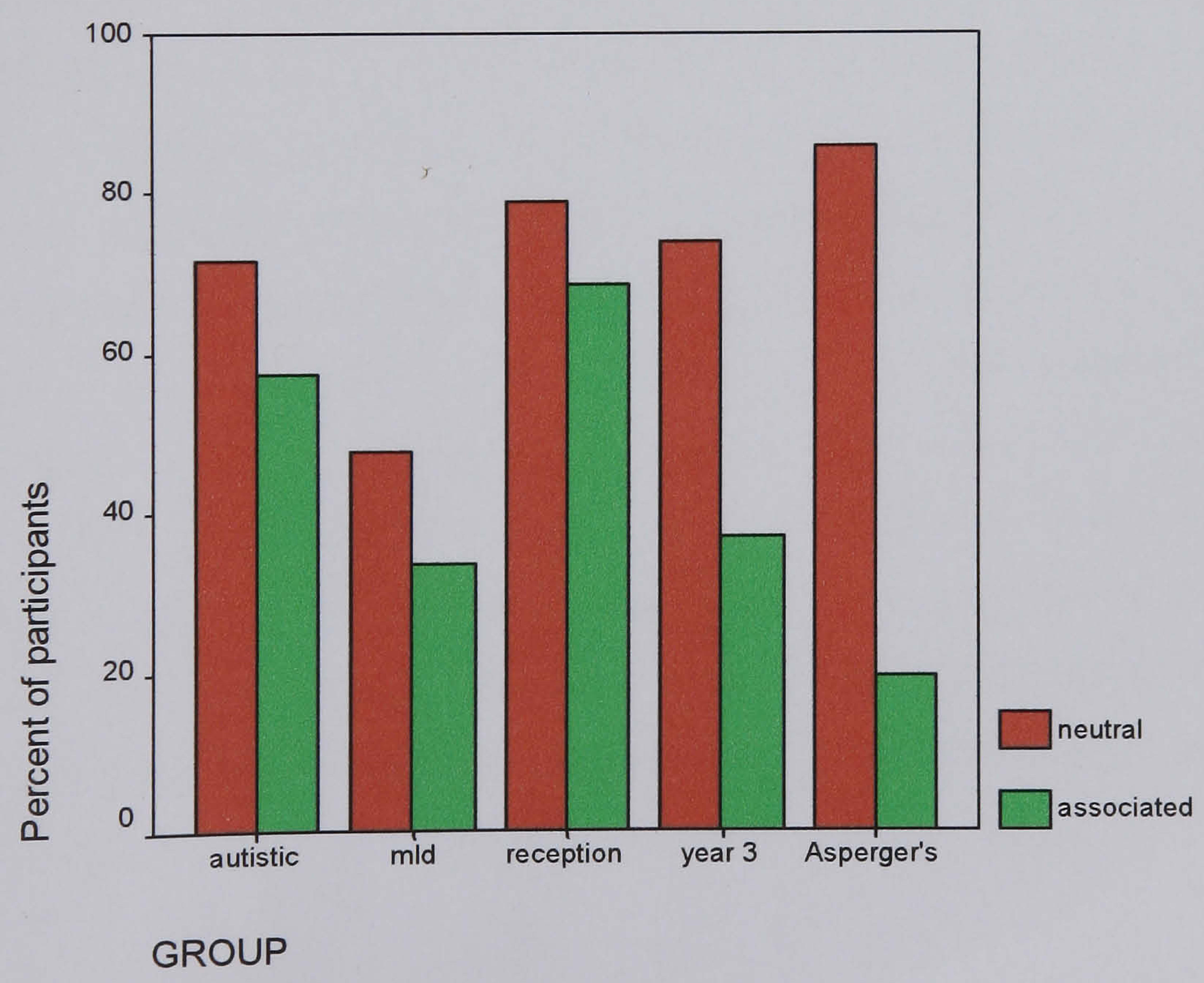


Histogram 2: Visual pairings for associated cards

A mixed ANOVA was carried out including participant group (5) and order (2) as between subject factors and condition (2) as a within subject factor. Results showed a significant effect of condition $\underline{F}(1,84)=79.99$, $\underline{p} < .001$, as well as a significant condition by group interaction $\underline{F}(4,84)=5.50$, $\underline{p} < .01$. Further analyses were carried out to compare between groups for each condition independently to clarify the interaction. There was a significant difference between groups on the neutral condition $\underline{F}(4,100)=2.49$, $\underline{p}<.05$. A post-hoc Tukey's test revealed that the reception group made significantly more visual pairings than the MLD group ($\underline{p}<.05$). Groups also differed significantly on the associated condition $\underline{F}(4,100)=2.97$, $\underline{p}<.05$. Post-hoc analysis showed that participants in the reception group used a visual pairing strategy significantly more than those with Asperger's syndrome ($\underline{p}<.05$). Wilcoxon analyses were carried out to check if participants judged differently between condition within each group. As indicated in Figure 5:6, all groups made significantly more visual pairings on the neutral than on the associated condition ($\underline{p}<.05$ in all cases).

Figure 5:6

Percentage of participants preferring to pair visually on the associated and neutral conditions



The analyses was repeated on the full set of data, including trials where individuals made identification errors. The results were the same as those obtained in the previous set of analyses, with the exception that on the post-hoc one-way ANOVA for the neutral condition the p-value fell just below significance $F(4,100)=2.39$, $p=.056$.

As in Experiment 5:1, analyses were carried out to investigate if any groups had a majority who preferred to pair visually. The number of individuals pairing visually on more and fewer than 50 percent of the trials for each condition (Table 5:4) was calculated. A significant majority matched over 50 percent of the cards visually in all groups (excluding MLD) on the neutral condition ($p<.05$ in all cases). In the MLD group an equal number of individuals fell above and below 50 percent. On the associated condition, although the majority of individuals with autism and those in the reception group made more visual pairings over 50 percent, this was not significant. The majority of individuals with Asperger's syndrome, MLD, and year 3 made visual pairings on fewer than 50 percent of trials. This was significant only in participants with Asperger's syndrome ($p<.025$).

Table 5:4.

Frequency of individual responses for Experiment 5:2

Group	condition	exactly 50%	below 50%	above 50%	χ^2	p value
autistic	associated	0	9	12	0.2	ns
	neutral	1	5	15	4.06	p<.05
MLD	associated	0	14	7	1.72	ns
	neutral	1	10	10	0	ns
reception	associated	1	5	13	2.72	ns
	neutral	2	2	15	8.48	p<.005
year 3	associated	0	12	7	0.84	ns
	neutral	3	2	14	7.56	p<.01
Asperger's	associated	1	16	4	6.05	p<.025
	neutral	2	1	18	13.48	p<.005

Note: All the analyses in the above table have 1 degree of freedom and have been adjusted using Yate's correction for continuity.

A multiple regression analysis was carried out to see if verbal ability predicted performance in the clinical groups. Differences in percentage scores (between conditions) were calculated for each individual whose data were entered into the main analysis. Participants with autism and Asperger's syndrome were combined into a single group as they had been in Experiment 5:1. Chronological age was entered in the first step: $R^2=.02$. In the second step, autistic subgrouping (autistic/ Asperger's) was added, which led to a significant increase in the 'explained' variance: $R^2=.30$, $F(1,39)=15.39$, $p<.01$. In the third step, VMA was entered, which led to a further significant increase in 'explained' variance: $R^2=.38$, $F(1,38)=5.03$, $p<.05$. Another regression was carried out entering these same variables in a different order. CA was again entered first. In the second step when VMA was added there was a significant increase in $R^2=.26$, $F(1,39)=12.65$, $p<.01$. There was also a significant increase in the final step when autistic subgrouping was entered $R^2=.38$, $F(1,38)=7.31$, $p<.01$. Apparently, autistic subgrouping predicted selection strategy independently of VMA. In particular, individuals with Asperger's syndrome judged differently between associated and neutral conditions to a greater extent than participants with autism, and this could not entirely be explained by differences in VMA.

In the MLD group, chronological aged was entered in the first step (R^2=.03) and VMA in the second: R^2=.27, $F(1,18)$=4.41, p<.05. As in Experiment 5:1, VMA accounted for variance associated with the tendency to judge differently between conditions independently of other predictors.

5:8 General discussion of experiments 5:1 and 5:2

With the exception of reception children in Experiment 5:1, more participants within each group chose a colour that visually matched the depicted object in the neutral (e.g. a red car) than in the associated (e.g. a blue banana) condition. These two conditions differed according to whether or not background knowledge of the object's typical colour could feed into the decision process. It seems participants with autism and Asperger syndrome successfully utilised background knowledge when pairing stimuli. There was no sign of 'less capture by meaning' compared with participants who did not have autism.

The results are consistent with Pring and Hermelin (1993), but also extend their findings in several ways. First, unlike in Pring and Hermelin's study, a visually based strategy would not have conflicted with fine attention to detail. In our study, participants could have paired the presented object (e.g. a blue banana) with a stimulus of identical colour (a blue patch of colour). It is notable that participants with autism preferred to pair with the associated colour regardless of that fact. Second, our findings cover more typical samples with autism, whereas Pring and Hermelin tested savant artists. Third, it was demonstrated that in a within-participant basis that those with autism judge differently between stimuli which have an associated colour and those which do not. Evidently, participants with autism are not influenced by background knowledge ad hoc, but only when appropriate.

If participants with autism had not judged differently between objects with and without an associated colour, this could either be interpreted at a pragmatic or a conceptual level. They might have suppressed the influence of background knowledge on thinking they were supposed to pair according to surface properties. Given that such a pragmatic interpretation is highly legitimate, and indeed that it could explain the judgments of children approximately age 5 in Experiment 5:1, it seems particularly notable that participants with autism paired objects with colours according to background associations.

Irrespective of patterns in the group data, some participants did not judge differently between conditions. In the associated condition, the data were bimodally distributed, with some choosing the visually matching colour and others choosing the semantically associated colour. Interestingly, VMA significantly predicted colour selection in the clinical populations. Thus, it appears that an over-riding preference to use surface information is generally linked with intellectual immaturity. However, in Experiment 5:2 participants with autism were less likely than those with Asperger's syndrome to judge differently between associated and neutral conditions. This could not be explained entirely by group differences in VMA.

There is a need to reconcile our finding that individuals with autism and Asperger's syndrome utilise background knowledge, with studies that suggest otherwise (Frith & Hermelin, 1969; Pring Hermelin, & Heavy, 1995; Shah & Frith, 1983; Frith & Snowling, 1983). I have already raised the possibility that cues inherent in the procedure led participants to pair pictures in the associated set with the object's normal colour. In Experiment 5:1, participants named the pictured objects before selecting a colour, which may have invoked a verbally-based association between object name and object colour (Davidoff & Mitchell, 1993; Mitchell et al., 1996). This could have prompted participants to select the normal colour in preference to the presented colour. Indeed, Tager-Flusberg (1991) found that cueing in the retrieval of word lists elicited semantically based processing in autism. In cued recall, participants performed similarly whether or not they had autism. In free recall, individuals with autism did not perform as well as participants in comparison groups. Arguably, individuals without autism formed links between items in the list, which facilitated recall. Perhaps those with autism did not form links unless they were prompted to do so by the cue. However, many individuals with autism and Asperger's syndrome systematically selected the normal colour in Experiment 5:2, despite the fact that they did not name the pictures until completing the pairing. Hence, they were influenced by background knowledge even in the absence of the cue connected with naming objects initially.

Still, the requirement for participants to choose a colour out of a set of 2 in both experiments could in itself serve as a cue. Although one colour was not intrinsically more conspicuous than another, the very fact that the normal colour was present could have alerted participants to the possibility of choosing it. Perhaps individuals with autism and Asperger's syndrome would have shown stronger preference for a visual pairing had they not been presented with a forced choice involving the normal colour. Even so, this potential cue was not sufficient to prompt selection of the normal colour in children aged 5, suggesting that it was not a particularly potent cue. At the very least, participants with autism must have been sufficiently attuned to background information to benefit from a very weak cue.

Further evidence suggesting that individuals with autism are attuned to background knowledge was reported by Ameli, Courchesne, Lincoln, Kaufman, and Grillon (1988). Participants were presented either with a set of pictures showing common objects or abstract designs. Later, they were shown the same set of pictures plus an additional unfamiliar item, which they were asked to single out. Individuals with and without autism were less likely to identify the new stimulus when the figures were abstract designs. Relative to individuals without autism, the performance of those with autism deteriorated to a greater extent for abstract designs than for meaningful pictures. Ironically, it seems they were even more affected by background knowledge than individuals without autism.

In the studies just cited, it seems individuals with autism were influenced by background knowledge when presented with a static display. Perhaps any weakness in using background knowledge to aid judgments would be apparent in a more complex task in which they had to processes sequential information, as in text comprehension or understanding the plot of a movie. In support of this possibility, Frith and Snowling (1983) reported a striking tendency for individuals with autism to pronounce ambiguous homographs according to their common meaning rather than to the meaning suggested by the textual context.

Conclusion

Prior research and theory suggests that individuals with autism might not be influenced by background knowledge to the same extent as individuals without autism (e.g. Frith, 1989). Accordingly, it was predicted that participants with autism would tend to select a visually matching colour for an incongruously coloured object in preference to the object's typical colour. This prediction was not supported: Individuals with autism were just as likely to select the normal colour as individuals without autism. At least in this task, background knowledge featured in processing.

CHAPTER SIX

General discussion and conclusions

6:1 Summary

Each experimental study has been presented and the findings have been discussed individually. In this chapter I will discuss the implication of these findings as a whole. I will begin by summarising the main findings from each of the studies.

6:2 Summary of findings from the visual illusion study

Experiment 3:1

An attempt was made to replicate Happe's findings showing that individuals with autism were less susceptible to illusions than those without autism. I modified Happe's procedure using a computer task as a more sophisticated measurement of illusion susceptibility. I also extended on Happe's study by including a group of individuals with Asperger's syndrome. Individuals with autism and Asperger's syndrome were found to be just as susceptible to illusions as individuals without autism when asked to manually adjust parts of the stimuli to appear the same on the computer.

Interpretation

Coherence does not appear to be weak at very low levels in autism. However, our failure to replicate previous findings (Happe, 1996) may have been a result of differences in procedure. In Happe's study (1996) individuals were required to make a verbal response, while in our task they were asked to make a manual response. It is possible that non-susceptibility to illusions may be confined to verbal responses made by individuals with autism.

Experiment 3:2

I wanted to ensure that the failure to replicate Happe's findings was not a result of methodological differences. Therefore, the same illusions were presented in Experiment 3:1 on cards and participants were asked to give verbal judgements about their appearance. For instance, they were asked if two lines appear to be the same or different in size. I also included two additional conditions (illusion different and control different) which showed both illusion and control stimuli so that they were physically different in size. Individuals with autism and Asperger's syndrome were susceptible to illusions when presented in this manner.

Interpretation

These findings suggest central coherence is intact at very low-levels in autism. They are just as susceptible to illusions whether required to respond verbally or manually. By chance, it is possible that those with autism in our study had exceptionally strong coherence ability which resulted in them being susceptible to illusory effects. Perhaps, Happe unwittingly selected a sample with unusually low levels of coherence.

6.3 Summary of findings from perception battery study

Experiment 4:1

I presented individuals with a battery of tests (believed to be associated with coherence ability) as well as the visual illusion computer task. Individuals with autism performed significantly better than verbal mental age matched controls on the block design, embedded figures and Rey complex figure test. Performance on these 3 tasks, correlated with one another. However, performance on these tasks did not strongly predict degree of susceptibility to illusions.

Interpretation

Unlike the illusion task, the block design, embedded figures, and Rey complex figure task are testing the same ability (i.e. possibly coherence). Superior performance on these tests by the autistic group provides evidence for weak coherence at a visuo-spatial constructional level. The fact that performance on the visuo-spatial tasks did not predict susceptibility provides further evidence that the illusions are not a good measure of coherence.

6.4 Summary of findings from visual and semantic processing study

Experiment 5:1

Participants were asked to pair pictures with the colour it went best with. For example, they were shown a blue banana and asked to select either a blue or yellow patch. They could rely on their background knowledge and choose the semantically related colour. Alternatively they might choose to pair pictures with the visually matching colour. Individuals with autism and Asperger's syndrome were like comparison groups in using a semantically driven strategy to pair objects with colours. The only exception was children aged 5 who preferred to select the visually matching colour.

Interpretation

Individuals with autism and Asperger's syndrome prefer to pair objects and colours according to background knowledge rather than visual properties of the stimuli. This is inconsistent with the idea of weak central coherence that suggests those with autism neglect meaningful context and show different patterns of attentional focus (less capture my meaning). However, those with autism and Asperger's syndrome might have been primed to pair semantically because they were asked to identify each picture initially. Perhaps, participants made a verbal association between the name and the typical colour of the target object.

Experiment 5:2

The same procedure was followed as in Experiment 5:1, except this time participants were asked to identify each picture only after they had paired it with a colour. This would eliminate any priming effect that might arise from naming. A preference to pair semantically persisted in those with autism and Asperger's syndrome even when they were not asked to identify the object initially.

Interpretation

Individuals with autism prefer to attend to semantic rather than visual information even when not primed initially by naming the object. These findings again fail to support the idea that background knowledge is less salient to an individual with autism as the theory of weak central coherence would predict. It remains a possibility that neglecting meaningful or contextual information is specific to particular tasks.

6:4 Discussion

Having summarised findings from each study individually I will now consider the implications they carry for the theory of weak central coherence in more detail. Happe (1999) argues that coherence is weak in autism at three different levels: perceptual, visuo-spatial constructional, and verbal-semantic. At different points in this thesis I have considered each of these levels. Therefore, in the following section I will discuss our findings in relation to these levels described by Happe.

Perceptual coherence

Evidence from Experiments 3:1, 3:2, and 4:1 suggests that individuals with autism are not less susceptible to illusions. This demonstrates that coherence is intact at a very low perceptual level in autism which contradicts Happe's (1996) findings. In Experiment 4:1 I proposed that individual differences in coherence ability might explain the conflicting findings between our study and Happe's. I argued that coherence ability could vary in the autistic and non-autistic populations, resulting in subgroups differing in susceptibility to illusions. Happe's study might therefore have recruited those individuals with autism who had extremely weak coherence. This explanation was ruled out however since no relationship between good performance on visuo-spatial tasks (associated with WCC) and susceptibility to illusions was found. These results are quite damaging to the claim that illusions are actually testing coherence.

How then can Happe's finding that individuals with autism were not susceptible to illusions be explained? It could be that some individuals with autism are less susceptible to illusions. However, Experiments 3:1, 3:2, and 4:1 indicate that this finding is not universal to all those with autism. Our findings also suggest that non susceptibility to illusions is not related to those tasks which have been argued most strongly to test weak central coherence (block design and embedded figures test). Thus, the mechanisms that allow us to perceive illusions, appear to be different than those that influence performance to be an obstacle on visuo-spatial tasks.

Perhaps visual illusions are not the best stimuli to use as a test of coherence at very low levels as there is still much debate as to how they actually operate. In Happe's study (1996) she presented individuals with illusions of various types. For example, she incorporated the Poggendorff which is an orientation illusion and the Ponzo which is a size illusion. The fact that she included illusions from various categories makes it even more difficult to believe coherence is the principal underlying mechanism for all of her stimuli. Even illusions of the same classification can vary in how they operate as there is a multitude of factors that may contribute to the illusory effect. These factors should be considered as they may interact with or even override coherence mechanisms.

In my investigations I chose to use only four size illusions (Muller-Lyer, Ponzo, Hat, and Titichener's circles) to minimise other possible explanations. However, I still failed to find a significant relationship between performance on these illusions. Size illusions have often been argued to operate on depth cues such as retinal disparity, convergence-accomodation, linear perspective, element and interspace size or frequency, overlay, and elevation (Day, 1972; Gregory, 1966). If these cues which normally help us to preserve the size constancy of an object are manipulated, then the apparent size of the object will be distorted. For example, our eyes have become accustomed to seeing objects which are indicated to be further away as smaller in size. If this rule is violated, as in the Ponzo illusion the object in the distance may look larger than an object of the same size in the foreground.

Mechanisms other than depth cues may also explain how size illusions work. For, example a study by Williams and Enns (1996) found that the effects of framing and depth were additive for the Hat illusion. One version of the Hat illusion is formed from two lines of equal length, one horizontal and one vertical. The two lines intersect to form an 'L' shape. The framing effect account argues that a line enclosed in a large frame appears to be shorter than a line of equal length in a small frame (Kunnapas, 1955). Kunnapas (1955) says that the ends of the vertical line are closer to the visual field boundary than the ends of the horizontal line, thus the vertical line appears longer. The size-constancy-scaling hypothesis, as I already discussed, argues that the vertical line is perceived as receding from the observer therefore it appears to be elongated even though it is the same size as the horizontal line. In order to determine which account best explained how this illusion operates Williams and Enns (1996) presented orthogonal variations in framing and depicted slant to individuals and asked them to judge whether or not the vertical line appeared longer. The manipulation of slant direction is said to influence strategies of pictorial-depth perception which may result in distortions of size. They found that the effects of framing and slant were independent and additive. This suggests that the illusory effect is determined by at least two different mechanisms. This demonstrates how an explanation of visual illusions may not be so straight forward. Since several mechanisms may cause the illusion, systematic manipulation of each factor is needed to understand to what extent each is contributing to the effect. Some illusions may rely on certain mechanisms more than others, which may explain why no correlation was found between the illusions in study 4:1.

Another variable that may make it even more difficult to interpret susceptibility to illusions is age. Some effects of illusions are known to increase with age while others decrease (Piaget, 1969). It might be that during development there is a shift from reliance on one perceptual mechanism to another. For example at an early age we might rely on retinal disparity to maintain size constancy, then use perspective cues at a later age. Thus, if an illusion operates primarily on retinal disparity than we would expect that younger individuals would be more susceptible to the illusion than older individuals. There was indeed a tendency for the effect of the Muller-Lyer illusion to decrease with age in experiment 3:1 and 4:1. Thus, it is possible that this may also explain why there was little correlation between the illusions.

If coherence were deficient at low levels in those with autism, one might expect them to have similar problems to individuals with integrative agnosia. This condition is caused by brain injury suffered as an adult that results in difficulty recognising objects due to an incapacity to integrate the various parts (Humphreys and Riddoch, 1987a, 1987b; Riddoch and Humphreys, 1987). A case study of an autistic savant (E.C.) by Mottron and Belleville (1993) demonstrated that E.C. showed normal perceptual analysis of shapes and objects, unlike those with integrative agnosia. Included in the battery of tests they carried out were tasks requiring the identification of fragmented figures as well as perception of illusions. E.C. showed no problems with integrating the components to perceive the gestalt in either of these tasks. It could be that those with autism may have integration deficits, but not as severe as an individual with integrative agnosia. If problems with integration were present at birth, then cerebral plasticity may allow for alternative processes to compensate for difficulties in this area. Thus, those with autism might show coherence deficits of a slightly different nature than an individual with integrative agnosia.

Alternatively, Mottron and Belleville (1993) suggest that the theory of weak central coherence may not adequately explain the perceptual problems in autism. They argue that difficulty with integrating elements into wholes is not a problem, rather it is a breakdown in the relationship between the local and global levels. This had become known as the theory of Hierarchical organisation. Evidence to support this comes from performance on the Navon (1977) task that looks at hierarchical organisation. Mottron and Belleville (1993) presented an autistic savant with the hierarchical task to investigate global/local processing of information. This task presents a larger unit (global) which consists of many smaller parts (local). The two levels may be congruent such as a large C made up of smaller C's. In this condition Mottron and Belleville (1993) found that the autistic savant (E.C.) made more local than global errors like control participants. When presented with incongruent stimuli (a large C made up of small O's), E.C. showed an increase in the number of global but not local errors. The results lead Mottron and Belleville to conclude that individuals with autism process information at the global level in a normal way, and the global does not have any special status over the local level.

This theory makes different predictions than the theory of WCC. It suggests that individuals with autism are capable of handling visual information at both the global and local levels, however it is the relationship between these two levels which is impaired.

Further evidence to support the hierarchisation deficit account comes from findings showing how those with autism judge and draw impossible figures (Mottron and Belleville, 1993; Mottron, Belleville and Menard, 1999). Perception of the local parts of an impossible figure will result in the coherent perception of the object. In order to perceive the "impossibility effect" one needs to integrate the local parts of the figure into a global percept. Mottron and Belleville (1993) asked individuals to judge whether a figure was possible or impossible. They found that an autistic savant made more errors than controls on judging impossible figures (e.g. Devil's fork and Penrose triangle). That is the individual with autism said the impossible figures were actually possible. In a later study Mottron, Belleville, and Menard (1999) asked 10 non-savant autistic individuals to draw impossible figures. They predicted that those with autism should experience less difficulty copying impossible figures because they would have difficulty relating the elements of the figure. Thus, an individual who would relate the local parts to the whole figure would find it quite confusing as they would perceive the "impossibility effect". They found that those with autism were less sensitive to geometric impossibility and thus took less time to draw them in comparison to control participants.

Happe (1996) argues integration of parts to form a whole is what is required to perceive the illusions in her study. However, perception of impossibility also requires one to perceive the interaction between the local and global levels. The fact that those with autism seem unimpaired in their perception of visual illusions but do have problems perceiving impossibility (studies 3:1, 3:2 and 4:1; Mottron and Belleville, 1993; Mottron, Belleville and Menard, 1999) suggests that perceptual abnormalities may not be a result of weak central coherence. Also, those with autism were able to draw the impossible figure as a whole, rather than a haphazard collection of fragments. This shows that coherence is not completely absent as they were capable of integrating pieces to form an intact figure. However, a deficit relating between the local and global level (Hierarchisation deficit) may still stand as an explanation. Further research is needed to see if individuals with autism only display perceptual abnormalities when one needs to perceive a relationship between the two levels.

Another possible explanation for why our findings differ from Happe's might be differences in procedure. In Experiment 3:1 individuals were asked to make manual adjustments when judging the illusory stimuli, whereas in Happe's (1996) procedure individuals made verbal judgements. Aglioti, DeSouza, and Goodale (1995) found differences in susceptibility to illusions according to whether an individual was required to make an explicit judgement of size or to reach out for the illusory stimulus. This study demonstrates that different ways of responding can indeed elicit different outcomes. However, in Experiment 3:2 when participants were asked to make a verbal response as in Happe's study, individuals with autism were still just as susceptible to illusions as comparison groups. It must be noted that in Experiment 3:2 there were additional conditions that her experiment did not have. This included control and illusion conditions showing the lines or circles to be judged as physically different. In Happe's study none of the stimuli for the size illusions (illusions or controls) were actually different. It is not exactly clear why those with autism might not be susceptible to illusions as a result of this difference. It is somewhat odd to think that the mere addition of "physically different" conditions in our study would cause an individual to be susceptible to an illusion. Perhaps those individuals in Happe's study had a bias to say "same".

Happe may have indeed stumbled across some individuals with autism who are not susceptible to illusions, but in light of our findings there is little evidence to suggest this is related to weak central coherence or characteristic of those with autism. In sum, our findings indicate that those with autism and Asperger's syndrome do not have deficits in coherence ability at a low perceptual level.

Visuo-spatial coherence

In Experiment 4:1 those with autism were superior to those without autism of the same verbal mental age on the block design, embedded figures, and Rey complex figure test. The only exception was in performance on the recognition trial of the Rey figure test where there were no significant differences in performance between groups. However, the recognition trial did not correlate as strongly with the other tasks suggesting it does not involve visuo-spatial skills to the same extent. These findings are consistent with weak central coherence at a visuo-spatial constructional level which supports previous research (Shah and Frith 1983; 1993). However, no superiority effect was found in those with Asperger's syndrome on these tests in comparison to control participants of a similar age. This conflicts with Jolliiffe and Baron-Cohen's (1997) study that found exceptional performance in those with Asperger's syndrome on the embedded figures test. It is possible that visuo-spatial superiority is not found in younger individuals with Asperger's syndrome. Those in our study had a CA of 11;10 and VMA of 9;11, whereas the individuals in Jolliffe and Baron-Cohen's study had a CA of 30;9 with average intelligence.

Perhaps, superior visual spatial skills in individuals with Asperger's syndrome develop in time through experience. If in childhood an individual has difficulty in making sense of the social world, they may become increasingly reliant on visual aspects of their environment. For example, if an individual is having difficulty following the plot of a play they may instead turn their attention to the curtains or background scenery. In time this could result in an exceptionally refined visual spatial system. This might explain why there was no evidence of superior visuo-spatial skills in younger individuals with Asperger's syndrome in Experiment 4:1.

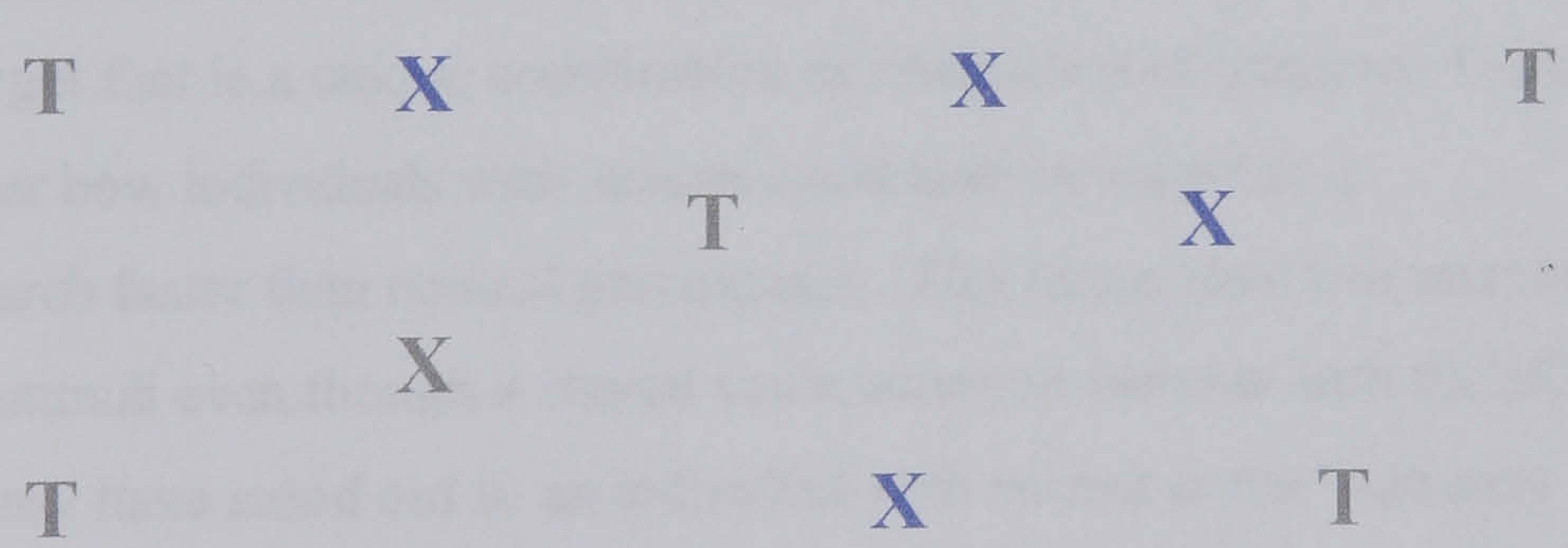
Another possible reason our findings are not fully consistent with previous findings may be our use of the adult version of the embedded figures test with a younger population. However, the manual says that testing children with this version is acceptable. Furthermore, this would not explain why those with Asperger's syndrome in our study also failed to excel on the other visuo-spatial tests (block design and Rey figures test).

Overall, our findings provide evidence that individuals with autism do better in comparison with mental age matched controls on visuo-spatial tasks. This is consistent with the theory of weak central coherence suggesting that there are deficits at a visuo-spatial constructional level as Happe (1999) described. However, superior ability on these tasks can also be explained in other ways.

An account of superior spatial ability has been suggested by Jolliffe and Baron-Cohen (1997) as an explanation for superior performance in those with autism and Asperger's syndrome on the embedded figures test. In addition, Plaisted, O'Riordan, and Baron-Cohen (1998b) also proposed that superior visual-spatial skills might explain why individuals did better on a conjunctive search task. This task requires an individual to identify a target letter (grey X) amongst other letters on a computer screen. The other letters share only one feature with the target letter (i.e. shape or colour). In order to perform well on a conjunctive search task one needs to be able to integrate features of the target (e.g. shape & colour) in order to be able to identify it as uniquely different from the others. Figure 6:1 illustrates an example of the task. Plaisted, et al. (1998b) argue that the exceptional performance of the autistic group on this task shows that they do not have problems integrating features as the theory of WCC would predict. One suggestion they make is that superior visuo-spatial skills might account for their results. However, this explanation was not supported when they failed to find a correlation between performance on the block design test and the conjunctive search task.

Figure 6:1

Conjunctive search task



Another problem with this explanation is that Shah and Frith (1993) argue that performance on the block design is not necessarily spatial in nature. They presented individuals with autism with the block design test but included stimuli with obliques and rotated some test items to see if these factors influenced performance. If those with autism had superior visuo-spatial skills then these manipulations should not matter. Shah and Frith (1993) did find that those with autism did significantly better than control groups when they had to visually segment the design in order to reconstruct it. However, they found that obliques and rotated designs affected individuals with autism to the same extent as those without autism. It was concluded that the superiority effect in those with autism was a result of exceptional segmentation skills rather than an overall visuo-spatial ability. Jolliffe and Baron-Cohen (1997) suggest superior segmentation skills or superior visuo-spatial skills may explain exceptional performance of those with autism on the embedded figures test. Our findings on the visuo-spatial tasks in Experiment 4:1 might be explained by either of these suggestions. However, it is uncertain which of these possibilities is more likely to be correct as the block design, embedded figures test, and Rey complex figure test are all visuo-spatial tasks and all would require segmentation to some extent.

Alternatively, it has been proposed that individuals with autism may process unique features extremely well and common features poorly (Plaisted, O'Riordan, Baron-Cohen, 1998b). They argue this would explain good performance on the conjunctive search task, embedded figures, and block design as all require superior item detection. In each of these the individual needs to find the appropriate target that is a unique combination or integration of features. I already discussed earlier how individuals with autism could find the target in a conjunctive search faster than control participants. This target item was unique from all other stimuli even though it shared some common features with the other stimuli. This may have stood out to an individual with autism as the "odd man out. On the embedded figures test one needs to find a target shape which is a unique combination of lines which are shared with different surrounding distracter shapes. Plaisted et al. 1998b argue that this can therefore be thought of as a within dimension search task which also requires some coherence ability like the conjunctive search task. An individual would need to be able to integrate lines or shapes to be able to identify the target figure.

Plaisted et al. argue that good processing of unique features can also explain superior performance on the block design test. However, this task differs in some important ways. An individual needs to find the correct block face to match part of a design. This is why Plaisted et al. (1998b) argue that good item detection skills would assist performance. However, before an individual could search for the appropriate block face they would need to first visually segment the design into parts in order to know what design they were looking for. This is slightly different than the conjunctive search task and the embedded figures task where the unique target is known to the individual beforehand. If an individual were good at item detection but poor at segmentation skills they might not be successful at the block design task. A good ability to segment in combination with exceptional ability to process unique features may however account for block design superiority. It may also be difficult to extend Plaisted et al's (1998b) argument to explain why I found those with autism did better than mental aged matched controls on the Rey figure copy test. Drawing is a complex task which requires an individual to perceive the figure, construct a representation, hold it in working memory, and finally make decisions about how to begin copying the figure. Fine motor skills may also influence performance on this task. It is unclear why superior detection of unique features would benefit an individual when there is no single target to identify. The person would need to focus attention on each element of the figure at some point in order to reconstruct it. The idea that individuals with autism show atypical perceptual skills because they process unique features well and common features poorly is still tenuous. This account needs to consider more carefully how it might explain superior performance on tasks such as the block design and good drawing ability in autism.

Verbal-semantic coherence

Finally the implications of these findings for the idea of coherence deficits at a semantic-verbal level must be considered. According to Frith (1989) a deficit in the central thought processes would cause an individual to show abnormalities in their direction of attention. She argues this explains clinical reports of autistic individuals attending to minor features in their environment while ignoring more important ones. In other words they focus on less relevant details at the expense of attending to the meaningful context. In Experiments 5:1 and 5:2 individuals with autism and Asperger's syndrome were just as likely to rely on semantic context as those without autism when pairing pictures with colours. This is inconsistent with previous literature suggesting that those with autism attend to different less meaningful aspects of a picture (Pring, Hermelin, and Heavey, 1995; Weeks and Hobson, 1987; Frith and Hermelin, 1969). However, our results are consistent with Pring and Hermelin's showing that meaning is just as salient to those with autism as those without it. Furthermore our study extends their findings to non-savant autistic populations. The outcome of these experiments questions the extent to which the theory of weak central coherence can predict how individuals with autism will process meaningful context. It also negates the earlier notion of "less capture by meaning" (Shah and Frith, 1983) which has now become encapsulated within the theory of weak central coherence. Brian and Bryson (1996) point out that those with autism may find embedded figures relatively easy in comparison to control participants because of "less capture by wholeness" or "less capture by meaning". They criticise previous findings on this test for not considering each of these alternatives individually. The theory of WCC does often conflate these two explanations. Future research in this area needs to be more specific about whether it is exploring how an individual with autism processes "meaning" or "wholeness".

The evidence makes it difficult to claim that individuals with autism have problems with coherence at a semantic-verbal level as Frith (1989) and Happe (1994a; 1999) argue. It seems those with autism neglect meaningful context only under some conditions. A more systematic investigation is needed to identify particular situations in which individuals with autism fail to process context or attend to different less important features. It may be that it is a specific type of context that individuals have difficulty processing. For example, the jigsaw puzzle task used in Pring, Hermelin and Heavey's experiment (1995) depicted people and animals. Perhaps, those with autism failed to use the meaningful content of the picture because it was aversive to them. Individuals with autism have been known to report that faces are often confusing and sometimes even frightening for them to look at (Grandin, 1995). They might be more likely to benefit from meaningful information if it were not social in nature. If they only had problems processing context when there was a social component this may indicate a deficit more with socio-cognitive processing rather than coherence.

Another reason for inconsistent findings in the literature might be that different tasks make it easier for an individual with autism to see a need to attend to meaningful context. Perhaps meaningful information does not immediately jump out to individuals with autism. However, given the appropriate cues they might utilise it in the same way as those without autism. I raised this idea in Experiment 5:1 suggesting priming cues from initially naming the stimuli may have allowed those with autism to employ a semantic strategy. However, this explanation was ruled out in Experiment 5:2 when participants were required to name the stimuli after the procedure and they still preferred the semantically related colour. The fact that reception aged children did prefer the visually matching colour demonstrates that the task did allow for alternative responses to be made. Thus, one cannot say that the task would only yield a semantic response from individuals. It is still possible that the design of our study may have been easier for individuals with autism to attend to meaningful information in favour of visual properties. Our task required an individual to make a choice between two colours. Perhaps in doing this attention was drawn to the two ways of doing the task. When individuals are presented with a jigsaw puzzle and asked to solve it they are not told they can either match up the lines or use the content of the picture to help them solve it. They are simply left to complete the puzzle any way they like. If a failure to process contextual information is restricted to particular circumstances, the theory of weak central coherence would need to specify the conditions when it would be a problem.

A study by Plaisted, Sweetenham, and Rees (1999) offers evidence that individuals with autism are capable of global processing if their attention is overtly primed. They presented individuals with two forms of the Navon task (1977). One type was a divided attention task and the other a selective attention task. They found that individuals with autism were successful at processing the global shape in the selective attention task but not in the divided attention task. In the selective attention task the individual was told to attend to one particular level. However, in the divided attention they had to search both levels for a particular target. Thus, they concluded that those with autism show typical global processing when their attention was cued to a particular level. If differences in task procedure can affect whether an individual with autism can process globally or not at a perceptual level, this may also be able to explain mixed findings at a semantic level.

If individuals with autism are capable of global processing when their attention is directed by a cue, this may suggest their difficulties lie more with executive functioning. Perhaps, automatically their attention is drawn to the local level but they have difficulty then shifting their attention to the global level unless primed to do so.
For example, Tager-Flusberg (1991) found individuals with autism were able use meaning to assist recall of words when given a cue such as "fruit". When the cue was not given they did not recall the related words (e.g. apple, pear) better than non-related words (e.g. car, chair) as those without autism did. In this case with a simple cue those with autism were able to focus on the thematically related words. Performance on an ambiguous homograph test might also be explained by problems with executive functioning (Snowling and Frith, 1986). When asked to read sentences such as "The actor took a bow". Participants gave the more common but incorrect pronunciation of the word "bow". Frith (1989) and Happe (1994a) argue this is a result of their failure to take the context of the sentence into account. However, another explanation could be that individuals with autism cannot help but give the preponent response.

Further research is needed to determine which of these possibilities, if any, may explain the inconsistent findings of how individuals with autism process meaningful context. Until then it is perhaps premature to conclude that coherence may be weak at a semantic-verbal level at least until other explanations are ruled out.

Altogether, these investigations failed to find problems with coherence at the three levels (perceptual, visuo-spatial constructional, and semantic-verbal) Happe (1999) describes. I did not find that individuals with autism perceived visual illusions differently than those without autism. Neither were differences found between these populations in their preference to use semantic information to pair objects with colours. These findings suggest that problems with coherence may not extend to low perceptual levels or to higher semantic-verbal levels. One might ask if this poses a problem for weak central coherence as an explanation of perceptual, social, and language abnormalities found in autism.

Frith's original formulation of weak central coherence assumed a certain level of local cohesion was intact in autism (Frith, 1989). Our findings in Chapter three support this. Basic abilities that individuals with autism do have demonstrate this. For example, most higher-functioning individuals with autism can read. This would involve the ability to perceive a relationship between letters to form a word as well as seeing a relationship between words to form a sentence. They can also recognise pictures and objects which would require the integration of lines and features. Thus, a deficit in coherence at low levels does not seem a likely explanation for perceptual abnormalities in autism.

The evidence of deficit in coherence at a visuo-spatial constructional level appears to be more stable. Experiment 4:1 not only found superior performance in autism on the block design, embedded figures, and Rey figure test (excluding recognition trial), but also found they correlated. This raises the question whether individuals with autism are simply better at visuo-spatial tasks or whether they excel in this area because of weak central coherence.

Finally, our findings in chapter five suggest that individuals with autism attend and utilise meaningful information in a similar way to those without autism. This appears to undermine the idea of WCC as an explanation of language and social abnormalities. The theory of WCC needs to be more specific in what areas it predicts there to be a problem at the semantic-verbal level. Also, other possible explanations of deficits at this level (i.e. socio-cognitive deficits) need to be ruled out.

6:5 Conclusion

The theory of weak central coherence needs refining in order to account for our failure to find evidence of coherence at a very low perceptual level and at a semantic verbal level. If the theory cannot be modified to make more specific and accurate predictions then alternative theories (hierarchisation theory, superior visual spatial skills, enhanced discrimination of unique stimuli, socio-cognitive deficits) may offer a more suitable explanation of features of autism.

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/

Appendix 3:1 Visual illusion program in Turbo pascal

Hat illusion

```
program prog01;  { v1.0 }

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           UK

  Written in TurboPascal 7.0

}

uses
   graph, crt;

var
   size            : integer;
   rkey            : char;

   condition       : integer;
   condition_list  : array[1..100] of integer;

   runloop         : integer;

   stimno          : integer;

   i,j,k           : integer; { Common loop variables }

   Results         : array[ 1..100 ] of integer;

   my_Outfile      : Text;
   my_OutputName   : String;
   my_Infile       : Text;
   my_InputName    : String;


{ ************************************************************************* }

procedure ClearAllArrays;
begin
     for i := 1 to 100 do begin
         Results[ i ] := 0;
     end;
end;

{ ************************************************************************* }

procedure GetUserInfo;
begin
     ClrScr;
```

```
     Writeln('Visual Illusion Program');
     Writeln('----------------------');
     Writeln;
     Writeln;
     Writeln('< - decrease size');
     Writeln('> - increase size');
     Writeln;
     Writeln('n - next trial');
     Writeln('Q - Quit and log results');
     Writeln;
     Writeln;
     Writeln;
     Writeln('Note: The maximum number of trials is limited to 100');
     Writeln;
     Writeln;
     Writeln;
     Writeln;



     Write('Enter Name of Input file : ');
     Readln(my_InputName);

     Write('Enter Name of Results file : ');
     Readln(my_OutputName);

     Assign(my_Outfile,my_OutputName);
     ReWrite(my_Outfile);

     Assign(my_Infile,my_InputName);
     Reset(my_Infile);

     stimno := 0;

     While not Eof(my_infile) do begin
       inc(stimno);
       readln(my_infile,condition_list[stimno]);
     end;

end;

{ ****************************************************************** }

procedure HR;
var
   GraphDriver : integer;
   GraphMode   : integer;
begin
  GraphDriver := vga;
  GraphMode   := vgahi;
  InitGraph(GraphDriver, GraphMode, '');
end;

{ ****************************************************************** }
{ ****************************************************************** }

   procedure draw_changing_stimulus;
```

```
var
   x,y : integer;
   yPos, xPos : integer;

begin


     { 1 the global position of the changing stimulus }
     yPos := 280;
     xPos := 260;

     { 2 the length of the lines }
     x := 50;
     y := 50;


     { 3 erase the old stimulus }

     setfillstyle(0,1);
     bar(xPos+x,0,xPos-x,500);

     { 4 draw the new stimulus }
     setcolor(15);
     setlinestyle(0,0,1);

     line( xPos, yPos, xPos+100, yPos);
     line( xPos, yPos, xPos, yPos-size);

end;
   procedure draw_changing_stimulus_pcontrol;

var
   x,y : integer;
   yPos, xPos :  integer;

begin

     x := 50;
     y := 50;

   {global position of control stimulus}
   yPos := 260;
   xPos := 240;

   {erase old stimulus}
    setfillstyle(0,1);
    bar(xPos+x,0,xPos-x,500);

   {draw new stimulus}
    setcolor(15);
    setlinestyle(0,0,1);


     line( xPos, yPos, xPos, yPos-size);
end;
```

```
procedure draw_fixed_stimulus_pcontrol;

var
   x,y : integer;
   yPos, xPos:  integer;
   fixed_size : integer;


begin
     { 1 the size of the fixed stimulus }

     fixed_size :=50;



     x := 50;
     y := 50;



   {global position of control stimulus}
    yPos := 350;
    xPos := 360;




   {erase old stimulus}
    setfillstyle(0,1);
    bar(xPos+x,0,xPos-x,500);

   {draw new stimulus}
    setcolor(15);
    setlinestyle(0,0,1);


    line( xPos, yPos+fixed_size, xPos, yPos-fixed_size);




end;



{ ********************************************************************** }
{ ********************************************************************** }

procedure LogTrial;
begin
    Results[ Runloop ] := (size *2) +1;
```

```
     size := 50;

     { if we want the changing stimulus to have a random start length }
     size := random(100)+25;
end;

{ ********************************************************************** }

procedure ResultsToDisk;
begin
     for i := 1 to stimno do begin
         writeln( my_outfile, Condition_list[i],' ',Results[ i ] );
     end;
end;

{ ************************* MAIN PROGRAM ******************************** }

begin
     randomize;

     ClearAllArrays;
     GetUserInfo;
     size := 50;

     { if we want the changing stimulus to have a random start length }
     size := random(100)+25;

     HR; { Set up graphics mode }

     rKey := 'X';

     for runloop := 1 to stimno do begin
       condition := condition_list[runloop];

       cleardevice;

     repeat
       case condition of

        1 : begin

             draw_changing_stimulus;
            end;

        2 : begin

             draw_changing_stimulus_pcontrol;
             draw_fixed_stimulus_pcontrol;
            end;
       end;

       rkey := readkey;

       if rkey = ',' then dec( size );
       if rkey = '.' then inc( size );

       if size  < 1 then size := 1;
```

```
       if size  > 125 then size := 125;

       if rkey = 'n' then LogTrial;

      until (rkey = 'n');
      rkey := 'X';
     end;

     ResultsToDisk;

     CloseGraph;

     Close( my_infile  );
     Close( my_outfile );

end.
```

Muller-Lyer Illusion

```
program prog02;  { v1.0 }


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           Birmingham
           B15 2TT
           UK

  Written in TurboPascal 7.0

}

uses
   graph, crt;

var
   size           : integer;
   rkey           : char;

   condition      : integer;
   condition_list : array[1..100] of integer;

   runloop        : integer;

   stimno         : integer;

   i,j,k          : integer; { Common loop variables }

   Results        : array[ 1..100 ] of integer;

   my_Outfile     : Text;
   my_OutputName  : String;
   my_Infile      : Text;
```

```
   my_InputName    : String;


{ ********************************************************************** }

procedure ClearAllArrays;
begin
     for i := 1 to 100 do begin
         Results[ i ] := 0;
     end;
end;

{ ********************************************************************** }

procedure GetUserInfo;
begin
     ClrScr;
     Writeln('Visual Illusion Program');
     Writeln('-----------------------');
     Writeln;
     Writeln;
     Writeln('< - decrease size');
     Writeln('> - increase size');
     Writeln;
     Writeln('n - next trial');
     Writeln('Q - Quit and log results');
     Writeln;
     Writeln;
     Writeln;
     Writeln('Note: The maximum number of trials is limited to 100');
     Writeln;
     Writeln;
     Writeln;
     Writeln;



     Write('Enter Name of Input file : ');
     Readln(my_InputName);

     Write('Enter Name of Results file : ');
     Readln(my_OutputName);

     Assign(my_Outfile,my_OutputName);
     ReWrite(my_Outfile);

     Assign(my_Infile,my_InputName);
     Reset(my_Infile);

     stimno := 0;

     While not Eof(my_infile) do begin
       inc(stimno);
       readln(my_infile,condition_list[stimno]);
     end;

end;
```

```
{ ************************************************************************** }

procedure HR;
var
   GraphDriver : integer;
   GraphMode   : integer;
begin
  GraphDriver := vga;
  GraphMode   := vgahi;
  InitGraph(GraphDriver, GraphMode, '');
end;

{ ************************************************************************** }
{ ************************************************************************** }
 procedure draw_changing_stimulus;
var
   x,y : integer;
   yPos, xPos : integer;
begin
     { 1 the global position of the changing stimulus }
     yPos := 200;
     xPos := 320;

     { 2 the length of the arms }
     x := 20;
     y := 20;

     { 3 erase the old stimulus }
     setfillstyle(1,0);
     bar(50,yPos-Y,590,yPos+y);

     { 4 draw the new stimulus }
     setcolor(15);
     setlinestyle(0,0,1);
     line( xPos-size, yPos, xPos+size, yPos);
     line( xPos-size, yPos, xPos-size-x,yPos-y);
     line( xPos-size, yPos, xPos-size-x,yPos+y);
     line( xPos+size, yPos, xPos+size+x,yPos-y);
     line( xPos+size, yPos, xPos+size+x,yPos+y);
end;

procedure draw_fixed_stimulus;
var
   x,y : integer;
   yPos, xPos : integer;
   fixed_size : integer;
begin
     { 1 the size of the fixed stimulus }
     fixed_size := 50;

     { 2 the global position of the changing stimulus }
     yPos := 280;
     xPos := 320;

     { 3 the length of the arms }
     x := 20;
```

```
    y := 20;

    { 4 draw the stimulus }
    setcolor(15);
    setlinestyle(0,0,1);
    line( xPos-fixed_size, yPos, xPos+fixed_size, yPos);
    line( xPos-fixed_size, yPos, xPos-fixed_size+x,yPos-y);
    line( xPos-fixed_size, yPos, xPos-fixed_size+x,yPos+y);
    line( xPos+fixed_size, yPos, xPos+fixed_size-x,yPos-y);
    line( xPos+fixed_size, yPos, xPos+fixed_size-x,yPos+y);
end;

procedure draw_changing_stimulus_nobar;
var
  x,y : integer;
  yPos, xPos : integer;
begin
    { 1 the global position of the changing stimulus }
    yPos := 200;
    xPos := 320;

    { 2 the length of the arms }
    x := 0;
    y := 0;

    { 3 erase the old stimulus }
    setfillstyle(1,0);
    bar(50,yPos-Y,590,yPos+y);

    { 4 draw the new stimulus }
    setcolor(15);
    setlinestyle(0,0,1);
    line( xPos-size, yPos, xPos+size, yPos);
    line( xPos-size, yPos, xPos-size-x,yPos-y);
    line( xPos-size, yPos, xPos-size-x,yPos+y);
    line( xPos+size, yPos, xPos+size+x,yPos-y);
    line( xPos+size, yPos, xPos+size+x,yPos+y);
end;
procedure draw_fixed_stimulus_nobar;
var
  x,y : integer;
  yPos, xPos : integer;
  fixed_size : integer;
begin
    { 1 the size of the fixed stimulus }
    fixed_size := 50;

    { 2 the global position of the changing stimulus }
    yPos := 280;
    xPos := 320;

    { 3 the length of the arms }
    x := 0;
    y := 0;

    { 4 draw the stimulus }
    setcolor(15);
```

```
    setlinestyle(0,0,1);
    line( xPos-fixed_size, yPos, xPos+fixed_size, yPos);
    line( xPos-fixed_size, yPos, xPos-fixed_size+x,yPos-y);
    line( xPos-fixed_size, yPos, xPos-fixed_size+x,yPos+y);
    line( xPos+fixed_size, yPos, xPos+fixed_size-x,yPos-y);
    line( xPos+fixed_size, yPos, xPos+fixed_size-x,yPos+y);
end;


{ ************************************************************************ }
{ ************************************************************************ }

procedure LogTrial;
begin
    Results[ Runloop ] := (size *2) +1;

    size := 50;

    { if we want the changing stimulus to have a random start length }
    size := random(100)+25;
end;

{ ************************************************************************ }

procedure ResultsToDisk;
begin
    for i := 1 to stimno do begin
        writeln( my_outfile, Condition_list[i],' ',Results[ i ] );
    end;
end;

{ ************************** MAIN PROGRAM ******************************* }

begin
    randomize;

    ClearAllArrays;
    GetUserInfo;
    size := 50;

    { if we want the changing stimulus to have a random start length }
    size := random(100)+25;

    HR; { Set up graphics mode }

    rKey := 'X';

    for runloop := 1 to stimno do begin
      condition := condition_list[runloop];

      cleardevice;

    repeat
      case condition of

       1 : begin
           draw_fixed_stimulus;
```

```
             draw_changing_stimulus;
            end;

        2 : begin
             draw_fixed_stimulus_nobar;
             draw_changing_stimulus_nobar;
            end;
       end;

       rkey := readkey;

       if rkey = ',' then dec( size );
       if rkey = '.' then inc( size );

       if size  < 1 then size := 1;
       if size  > 125 then size := 125;

       if rkey = 'n' then LogTrial;

      until (rkey = 'n');
      rkey := 'X';
     end;

     ResultsToDisk;

     CloseGraph;

     Close( my_infile  );
     Close( my_outfile );

end.
```

Ponzo illusion

```
program prog02;  { v1.0 }


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  Written in TurboPascal 7.0

}

uses
    graph, crt;

var
   size              : integer;
   rkey              : char;
```

```
    condition      : integer;
    condition_list : array[1..100] of integer;

    runloop        : integer;

    stimno         : integer;

    i,j,k          : integer; { Common loop variables }

    Results        : array[ 1..100 ] of integer;

    my_Outfile     : Text;
    my_OutputName  : String;
    my_Infile      : Text;
    my_InputName   : String;


 { ************************************************************************** }

 procedure ClearAllArrays;
 begin
      for i := 1 to 100 do begin
          Results[ i ] := 0;
      end;
 end;

 { ************************************************************************** }

 procedure GetUserInfo;
 begin
      ClrScr;
      Writeln('Visual Illusion Program');
      Writeln('-----------------------');
      Writeln;
      Writeln;
      Writeln('< - decrease size');
      Writeln('> - increase size');
      Writeln;
      Writeln('n - next trial');
      Writeln('Q - Quit and log results');
      Writeln;
      Writeln;
      Writeln;
      Writeln('Note: The maximum number of trials is limited to 100');
      Writeln;
      Writeln;
      Writeln;
      Writeln;



      Write('Enter Name of Input file : ');
      Readln(my_InputName);

      Write('Enter Name of Results file : ');
      Readln(my_OutputName);
```

```
     Assign(my_Outfile,my_OutputName);
     ReWrite(my_Outfile);

     Assign(my_Infile,my_InputName);
     Reset(my_Infile);

     stimno := 0;

     While not Eof(my_infile) do begin
       inc(stimno);
       readln(my_infile,condition_list[stimno]);
     end;

end;

{ ************************************************************************ }

procedure HR;
var
   GraphDriver : integer;
   GraphMode   : integer;
begin
  GraphDriver := vga;
  GraphMode   := vgahi;
  InitGraph(GraphDriver, GraphMode, '');
end;

{ ************************************************************************ }
{ ************************************************************************ }

procedure draw_changing_stimulus;
var
   x,y : integer;
   yPos, xPos : integer;
begin
     { 1 the global position of the changing stimulus }
     yPos := 280;
     xPos := 320;

     { 3 erase the old stimulus }
     setfillstyle(1,0);
     bar(xpos-round(size/2)-1,yPos-round(size/2)-
1,xpos+round(size/2)+1,yPos+round(Size/2)+1);

     { 4 draw the new stimulus }
     setcolor(15);
     setlinestyle(0,0,1);

     circle(xpos,ypos,round(size/2));


end;

procedure draw_fixed_stimulus;
var
   x,y : integer;
```

```
   yPos, xPos,y1Pos,x1Pos, x2Pos : integer;
   fixed_size : integer;
begin
     { 1 the size of the fixed stimulus }
     fixed_size := 50;

     { 2 the global position of the fixed stimulus }
     yPos := 120;
     xPos := 320;

     { 4 draw the new stimulus }
     setcolor(15);
     setlinestyle(0,0,1);

     circle(xpos,ypos,round(fixed_size/2));

     y1Pos := 80;
     x1Pos := 350;
     x2Pos := 290;

     setcolor(15);
     setlinestyle(0,0,1);
     line(x1Pos,y1Pos,x1Pos+100,y1Pos+280);
     line(x2Pos,y1Pos,x2Pos-100,y1Pos+280)

end;

procedure draw_changing_stimulus_pcontrol;
var
   x,y : integer;
   yPos, xPos : integer;
begin
     { 1 the global position of the changing stimulus }
     yPos := 280;
     xPos := 320;

     { 3 erase the old stimulus }
     setfillstyle(1,0);
     bar(xpos-round(size/2)-1,yPos-round(size/2)-
1,xpos+round(size/2)+1,yPos+round(Size/2)+1);

     { 4 draw the new stimulus }
     setcolor(15);
     setlinestyle(0,0,1);

     circle(xpos,ypos,round(size/2));


end;

procedure draw_fixed_stimulus_pcontrol;
var
   x,y : integer;
   yPos, xPos,y1Pos,x1Pos, x2Pos : integer;
   fixed_size : integer;
begin
     { 1 the size of the fixed stimulus }
```

```
    fixed_size := 50;

    { 2 the global position of the fixed stimulus }
    yPos := 120;
    xPos := 320;

    { 4 draw the new stimulus }
    setcolor(15);
    setlinestyle(0,0,1);

    circle(xpos,ypos,round(fixed_size/2));

    y1Pos := 80;
    x1Pos := 350;
    x2Pos := 290;


    end;
{ ********************************************************************** }
{ ********************************************************************** }

procedure LogTrial;
begin
    Results[ Runloop ] := (size *2) +1;

    size := 50;

    { if we want the changing stimulus to have a random start length }
    size := random(100)+25;
end;

{ ********************************************************************** }

procedure ResultsToDisk;
begin
    for i := 1 to stimno do begin
        writeln( my_outfile, Condition_list[i],' ',Results[ i ] );
    end;
end;

{ ************************** MAIN PROGRAM ******************************** }

begin
    randomize;

    ClearAllArrays;
    GetUserInfo;
    size := 50;

    { if we want the changing stimulus to have a random start length }
    size := random(100)+25;

    HR; { Set up graphics mode }

    rKey := 'X';

    for runloop := 1 to stimno do begin
```

```
      condition := condition_list[runloop];

      cleardevice;

    repeat
      case condition of

       1 : begin
            draw_fixed_stimulus;
            draw_changing_stimulus;
           end;

       2 : begin
            draw_fixed_stimulus_pcontrol;
            draw_changing_stimulus_pcontrol;
           end;
      end;

      rkey := readkey;

      if rkey = ',' then dec( size );
      if rkey = '.' then inc( size );

      if size  < 1 then size := 1;
      if size  > 125 then size := 125;

      if rkey = 'n' then LogTrial;

     until (rkey = 'n');
     rkey := 'X';
    end;

    ResultsToDisk;

    CloseGraph;

    Close( my_infile  );
    Close( my_outfile );

end.
```

Titchener illusion

```
program prog02;  { v1.0 }


{ (C) 1997 Dept. of Psychology
           Birmingham University
           Edgbaston
           Birmingham
           B15 2TT
           UK

  Written in TurboPascal 7.0
```

```
}

uses
    graph, crt;

var
   size            : integer;
   rkey            : char;

   condition       : integer;
   condition_list : array[1..100] of integer;

   runloop         : integer;

   stimno          : integer;

   i,j,k           : integer; { Common loop variables }

   Results         : array[ 1..100 ] of integer;

   my_Outfile      : Text;
   my_OutputName   : String;
   my_Infile       : Text;
   my_InputName    : String;

{ ********************************************************************** }

procedure ClearAllArrays;
begin
     for i := 1 to 100 do begin
          Results[ i ] := 0;
     end;
end;

{ ********************************************************************** }

procedure GetUserInfo;
begin
     ClrScr;
     Writeln('Visual Illusion Program');
     Writeln('-----------------------');
     Writeln;
     Writeln;
     Writeln('< - decrease size');
     Writeln('> - increase size');
     Writeln;
     Writeln('n - next trial');
     Writeln('Q - Quit and log results');
     Writeln;
     Writeln;
     Writeln;
     Writeln('Note: The maximum number of trials is limited to 100');
     Writeln;
     Writeln;
     Writeln;
     Writeln;
```

```
     Write('Enter Name of Input file : ');
     Readln(my_InputName);

     Write('Enter Name of Results file : ');
     Readln(my_OutputName);

     Assign(my_Outfile,my_OutputName);
     ReWrite(my_Outfile);

     Assign(my_Infile,my_InputName);
     Reset(my_Infile);

     stimno := 0;

     While not Eof(my_infile) do begin
       inc(stimno);
       readln(my_infile,condition_list[stimno]);
     end;

end;

{ ********************************************************************** }

procedure HR;
var
   GraphDriver : integer;
   GraphMode   : integer;
begin
  GraphDriver := vga;
  GraphMode   := vgahi;
  InitGraph(GraphDriver, GraphMode, '');
end;


{ ********************************************************************** }
{ ********************************************************************** }

procedure draw_changing_stimulus;
var
   x,y : integer;
   yPos, xPos,y1Pos,x1Pos, x2Pos,y2Pos,y3Pos, x3Pos,y4Pos,x4Pos,
   y5Pos,x5Pos,y6Pos,x6Pos : integer;
   fixed_size: integer;
begin
    { 1 the global position of the changing stimulus }

    fixed_size:=30;

    yPos := 280;
    xPos := 125;

    y1Pos := 300;
    x1Pos := 165;
```

```
     y2Pos := 330;
     x2Pos := 125;
     y3Pos := 300;
     x3Pos := 85;

     y4Pos := 255;
     x4Pos := 165;
     y5Pos := 230;
     x5Pos := 125;
     y6Pos := 255;
     x6Pos := 85;

     { 3 erase the old stimulus }
     setfillstyle(1,0);
     bar(xpos-round(size/2)-1,yPos-round(size/2)-
1,xpos+round(size/2)+1,yPos+round(Size/2)+1);

     { 4 draw the new stimulus }
     setcolor(15);
     setlinestyle(0,0,1);

     circle(xpos,ypos,round(size/2));
     circle(x1pos,y1pos,round(fixed_size/3));
     circle(x2pos,y2pos,round(fixed_size/3));
     circle(x3pos,y3pos,round(fixed_size/3));

     circle(x4pos,y4pos,round(fixed_size/3));
     circle(x5pos,y5pos,round(fixed_size/3));
     circle(x6pos,y6pos,round(fixed_size/3));

end;

procedure draw_fixed_stimulus;
var
   x,y : integer;
   yPos, xPos,y1Pos,x1Pos, x2Pos,y2Pos,y3Pos, x3Pos,y4Pos,x4Pos,
   y5Pos,x5Pos,y6Pos,x6Pos : integer;

   fixed_size : integer;
begin
     { 1 the size of the fixed stimulus }
     fixed_size := 30;

     { 2 the global position of the fixed stimulus }
     yPos := 280;
     xPos := 425;


     y1Pos := 313;
     x1Pos := 485;
     y2Pos := 340;
     x2Pos := 425;
     y3Pos := 313;
     x3Pos := 365;

     y4Pos := 247;
     x4Pos := 485;
```

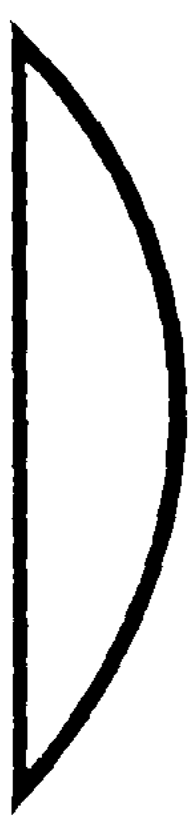
```
      y5Pos := 220;
      x5Pos := 425;
      y6Pos := 247;
      x6Pos := 365;

      { 4 draw the new stimulus }
      setcolor(15);
      setlinestyle(0,0,1);

      circle(xpos,ypos,round(fixed_size/2));

      circle(x1pos,y1pos,round(fixed_size/1));
      circle(x2pos,y2pos,round(fixed_size/1));
      circle(x3pos,y3pos,round(fixed_size/1));

      circle(x4pos,y4pos,round(fixed_size/1));
      circle(x5pos,y5pos,round(fixed_size/1));
      circle(x6pos,y6pos,round(fixed_size/1));



 end;
procedure draw_changing_stimulus_pcontrol;
var
   x,y : integer;
   yPos, xPos : integer;
begin
     { 1 the global position of the changing stimulus }
     yPos := 280;
     xPos := 125;

     { 3 erase the old stimulus }
     setfillstyle(1,0);
     bar(xpos-round(size/2)-1,yPos-round(size/2)-
1,xpos+round(size/2)+1,yPos+round(Size/2)+1);

     { 4 draw the new stimulus }
     setcolor(15);
     setlinestyle(0,0,1);

     circle(xpos,ypos,round(size/2));


end;

procedure draw_fixed_stimulus_pcontrol;
var
   x,y : integer;
   yPos, xPos,y1Pos,x1Pos, x2Pos : integer;
   fixed_size : integer;
begin
     { 1 the size of the fixed stimulus }
     fixed_size := 30;

     { 2 the global position of the fixed stimulus }
     yPos := 280;
```

```
     xPos := 425;

     { 4 draw the new stimulus }
     setcolor(15);
     setlinestyle(0,0,1);

     circle(xpos,ypos,round(fixed_size/2));


     end;
{ ************************************************************************ }
{ ************************************************************************ }


procedure LogTrial;
begin
     Results[ Runloop ] := (size *2) +1;

     size := 50;

     { if we want the changing stimulus to have a random start length }
     size := random(45)+25;
end;

{ ************************************************************************ }

procedure ResultsToDisk;
begin
     for i := 1 to stimno do begin
         writeln( my_outfile, Condition_list[i],' ',Results[ i ] );
     end;
end;

{ ************************** MAIN PROGRAM ******************************* }

begin
     randomize;

     ClearAllArrays;
     GetUserInfo;
     size := 50;

     { if we want the changing stimulus to have a random start length }
     size := random(45)+25;

     HR; { Set up graphics mode }

     rKey := 'X';

     for runloop := 1 to stimno do begin
       condition := condition_list[runloop];

       cleardevice;

     repeat
       case condition of
```

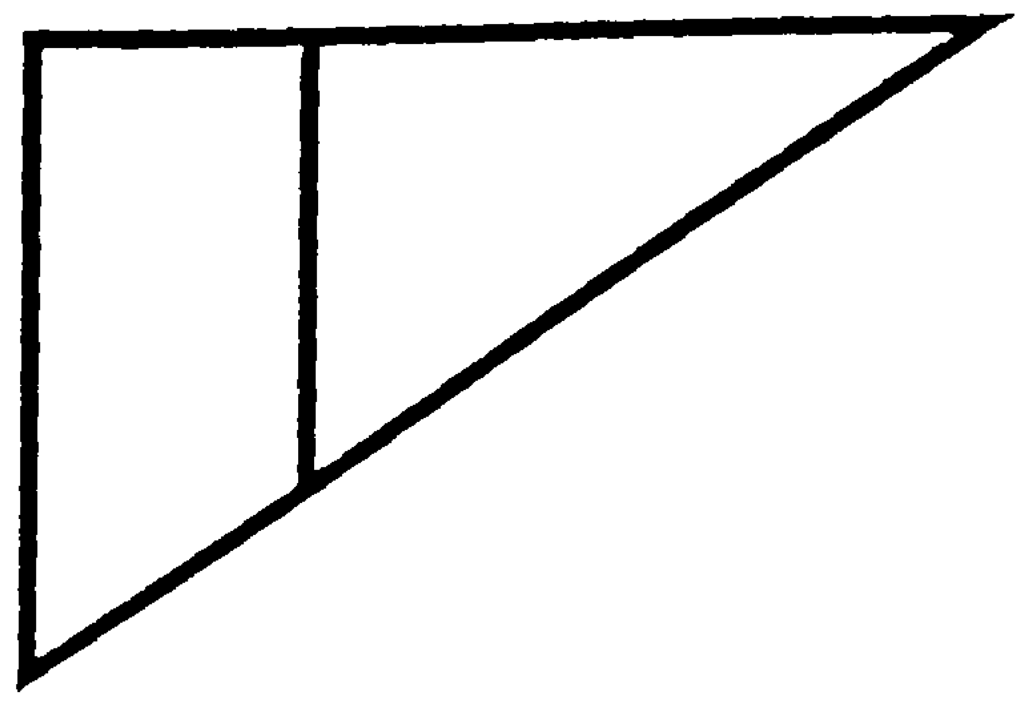
```
        1 : begin
             draw_fixed_stimulus;
             draw_changing_stimulus;
            end;

        2 : begin
             draw_fixed_stimulus_pcontrol;
             draw_changing_stimulus_pcontrol;
            end;
      end;

      rkey := readkey;

      if rkey = ',' then dec( size );
      if rkey = '.' then inc( size );

      if size  < 1 then size := 1;
      if size  > 70 then size := 70;

      if rkey = 'n' then LogTrial;

     until (rkey = 'n');
     rkey := 'X';
    end;

    ResultsToDisk;

    CloseGraph;

    Close( my_infile  );
    Close( my_outfile );

end.
```

Appendix 4:1 Stimuli for Rey complex figure recognition task

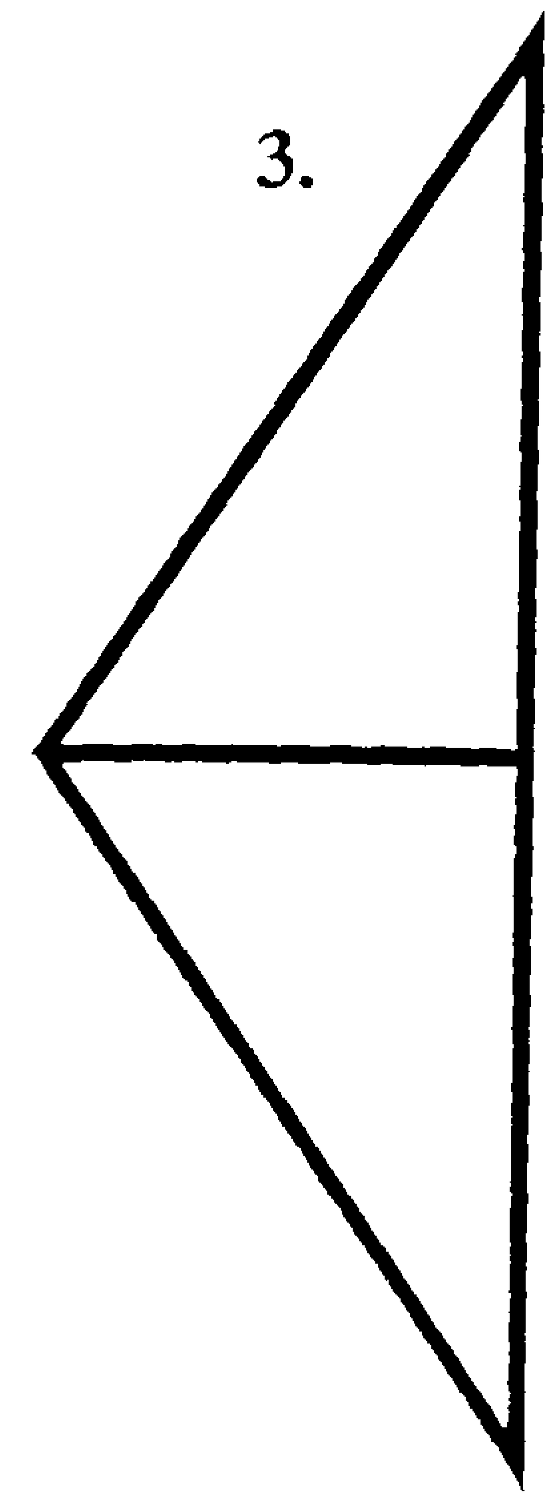
1.



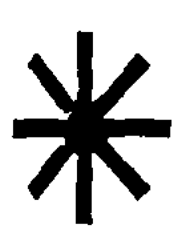
2.



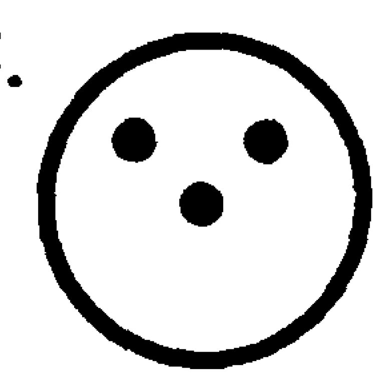
3.



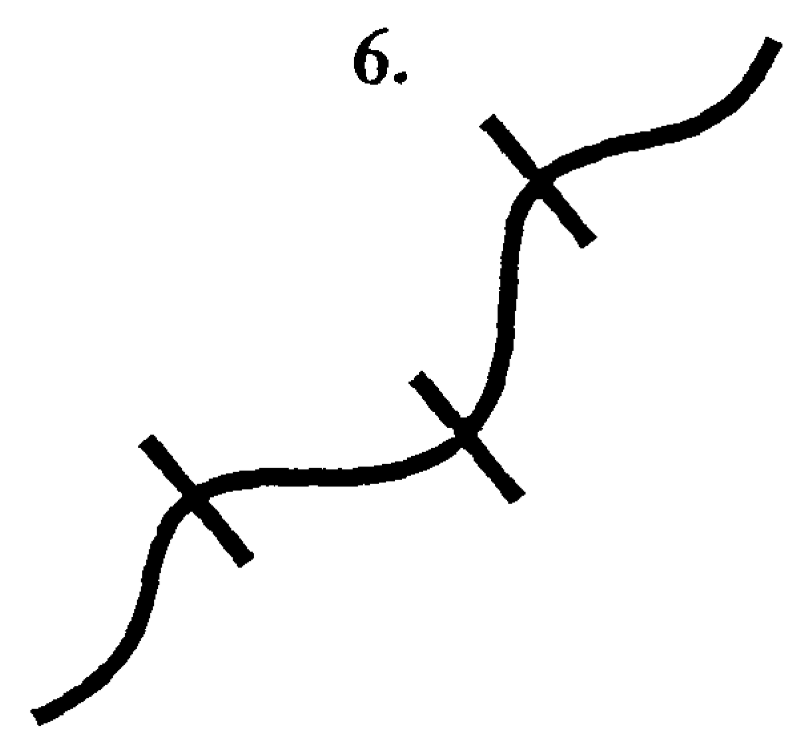
4.

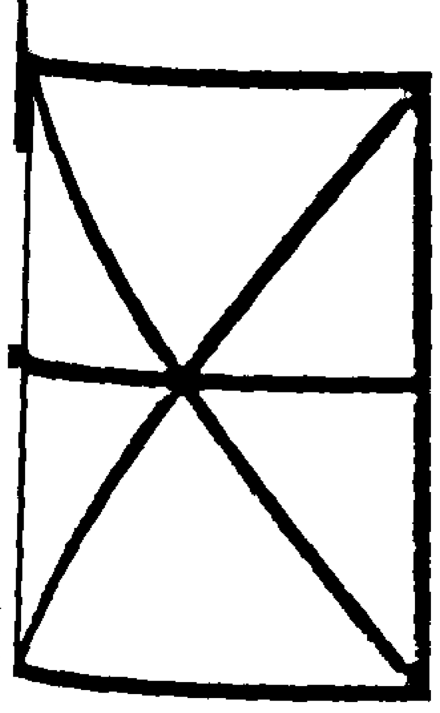


5.

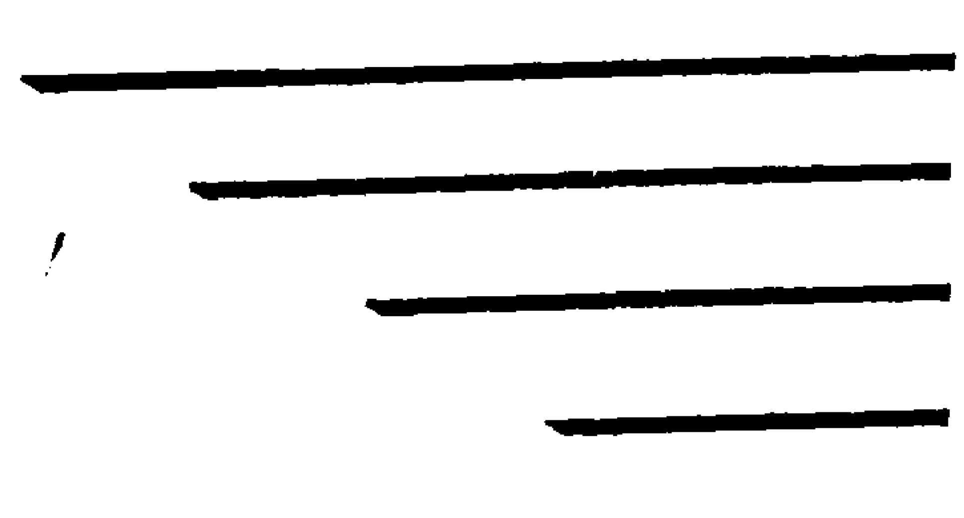


6.

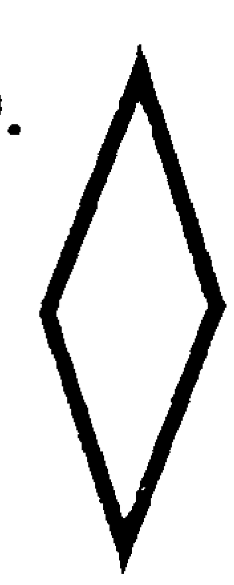




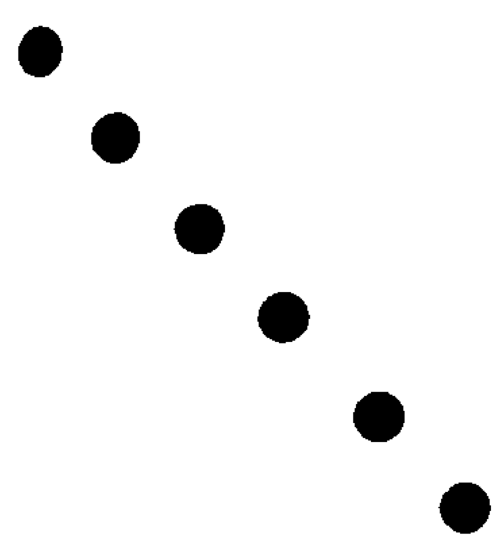
8.



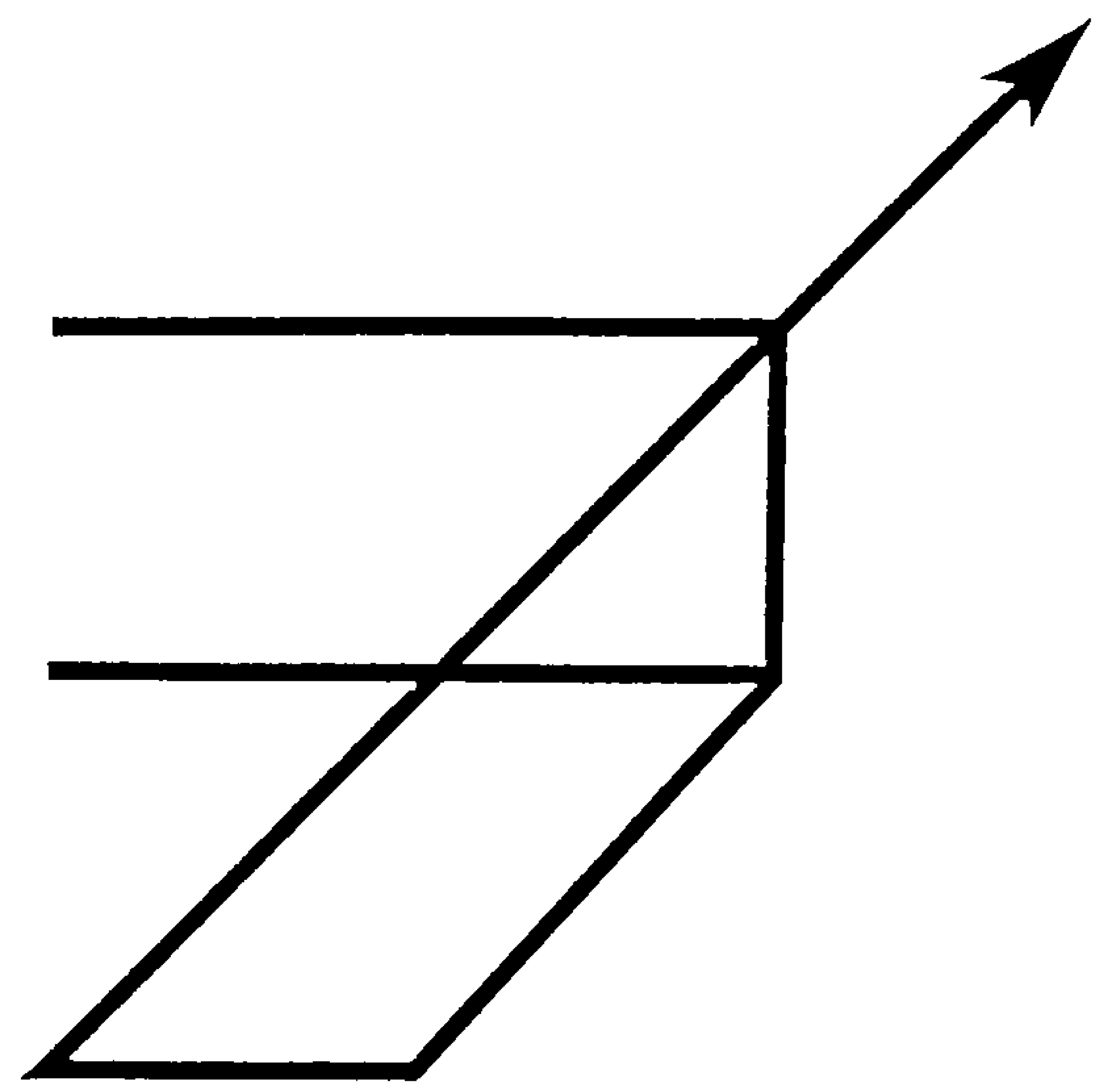
9.



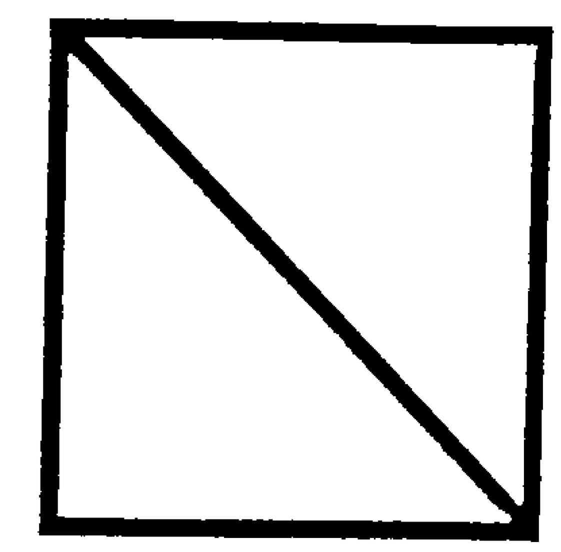
10.



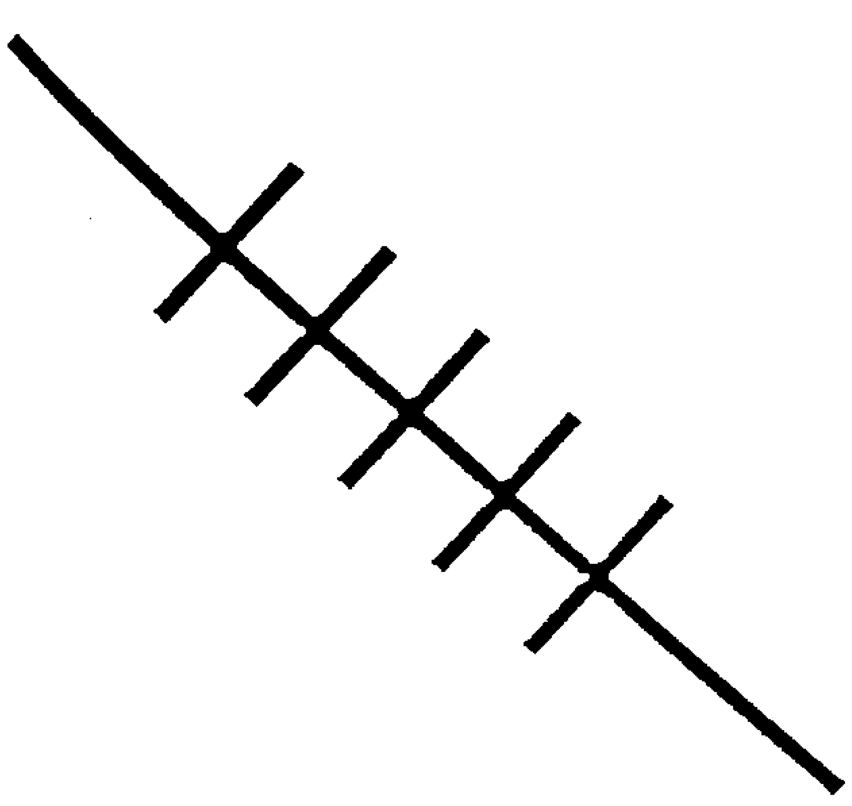
11.



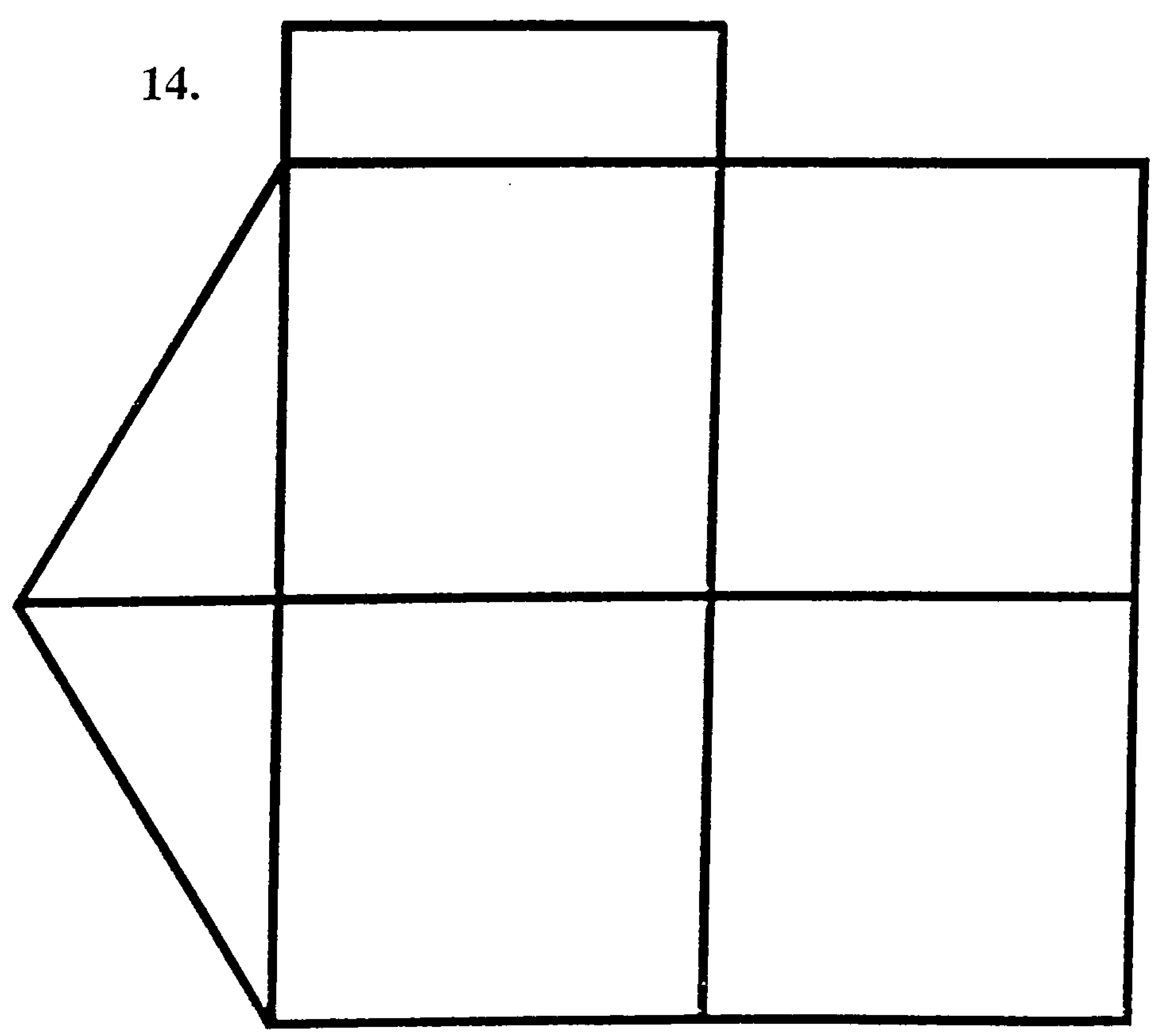
12.



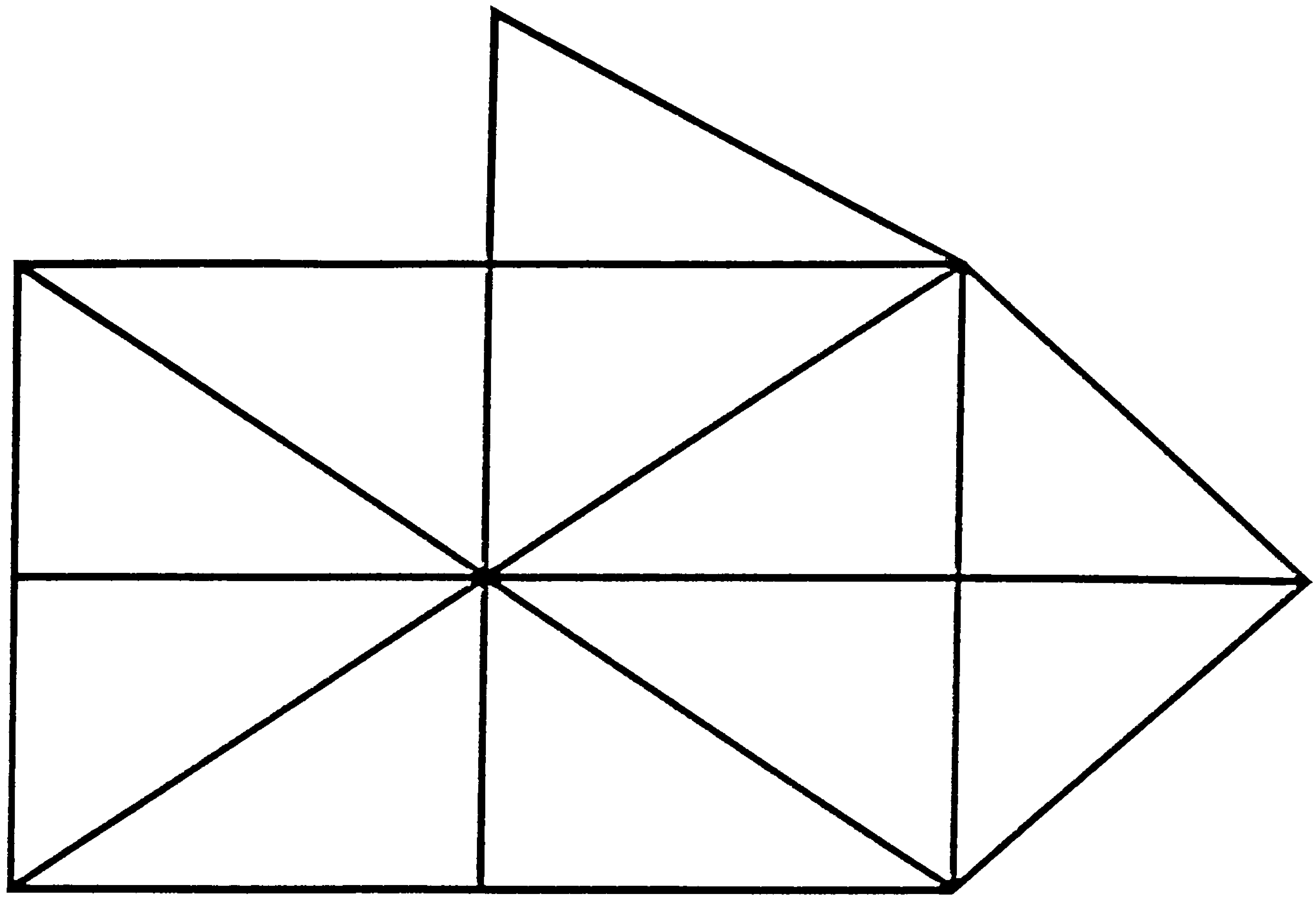
13.



14.

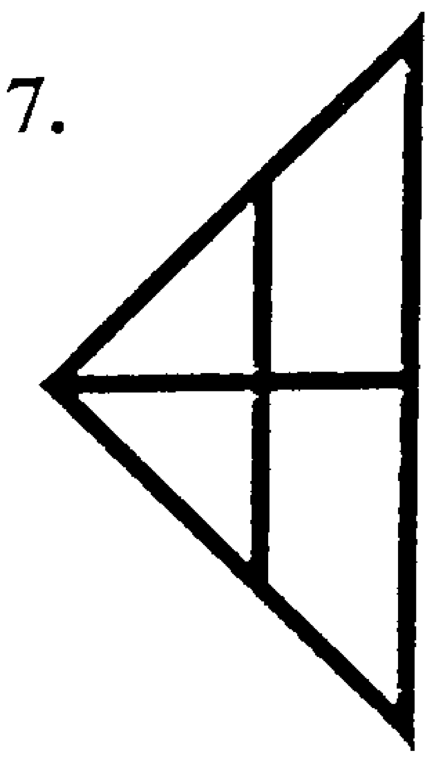


15.

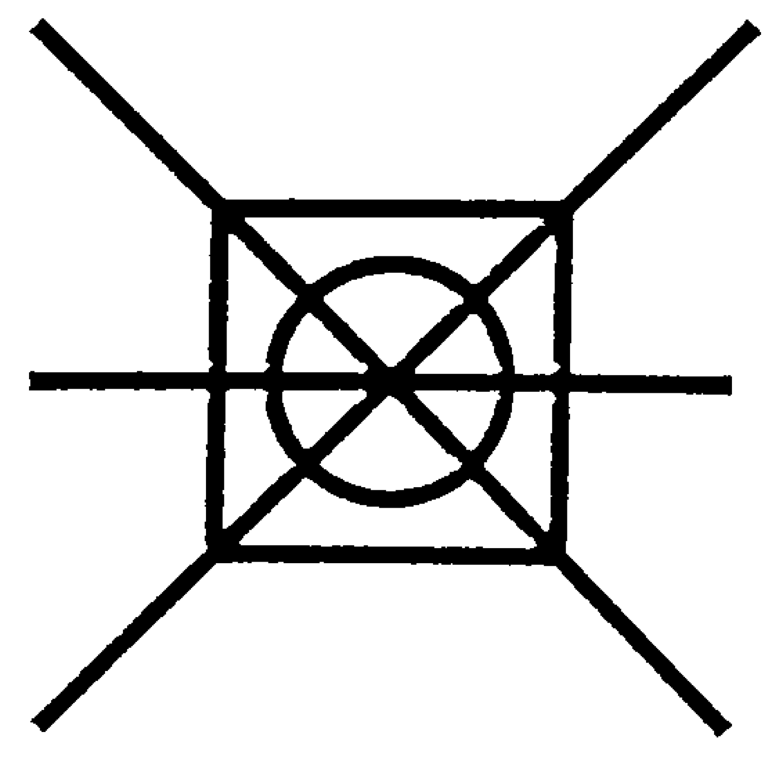


16.

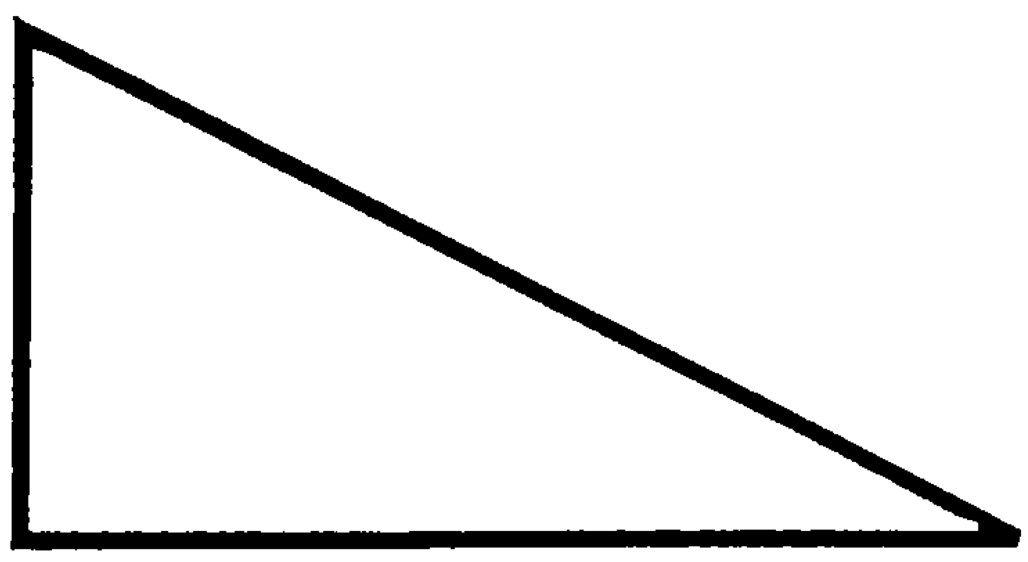
17.



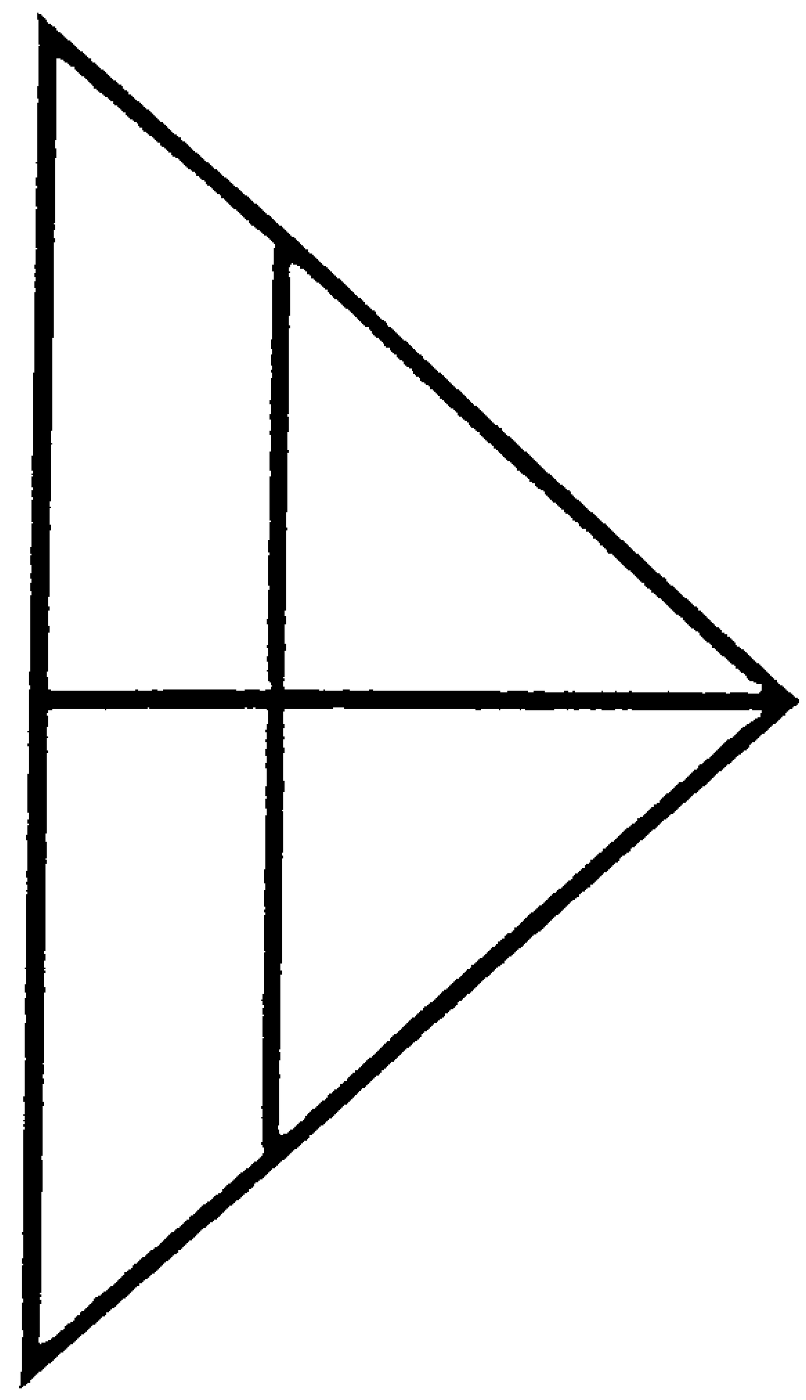
18.



19.

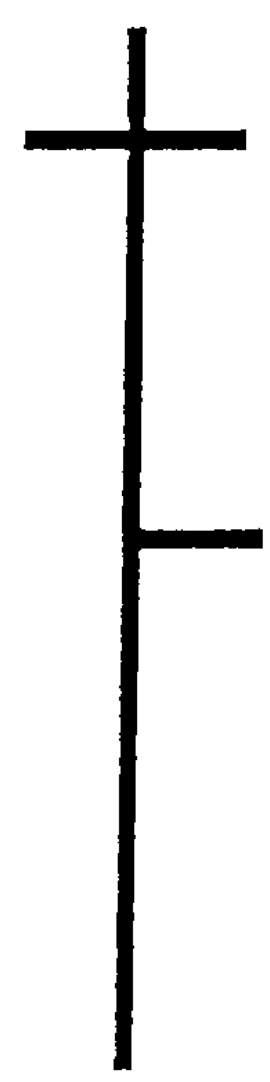


20.

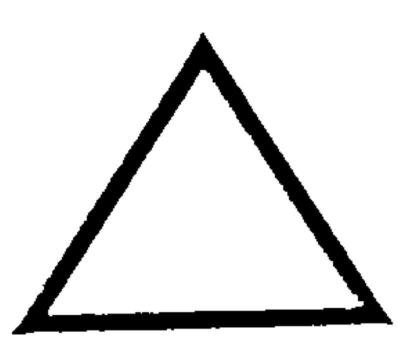


21.

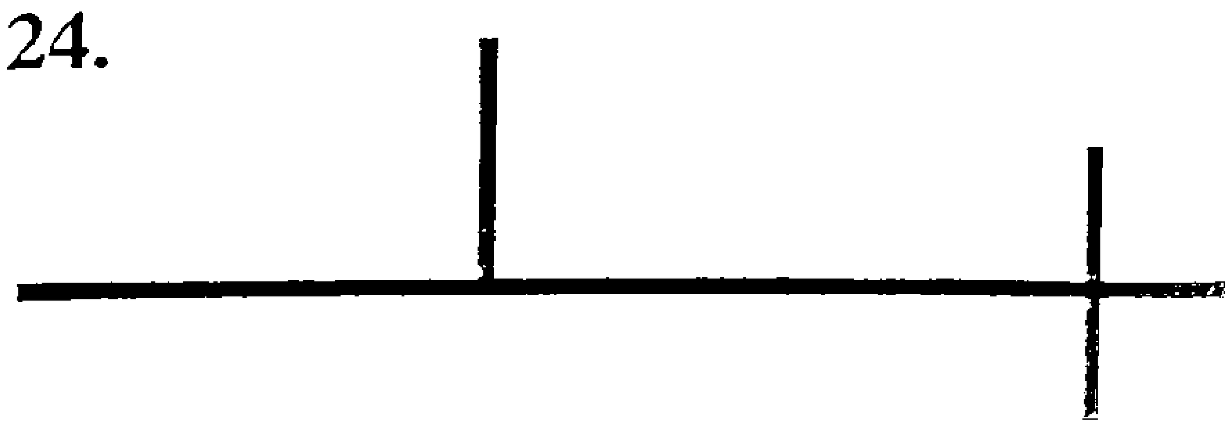
22.



23.



24.



Appendix 5:1 Stimuli for Experiments 5:1 and 5:2

Colour-associated cards

Object	Top	Bottom
1.) strawberry	red	yellow
2.) lemon	red	yellow
3.) frog	red	green
4.) fire engine	brown	red
5.) banana	yellow	blue
6.) carrot	blue	orange
7.) tree	green	orange
8.) pumpkin	orange	green
9.) chocolate	yellow	brown
10.) policeman	blue	brown
11.) monkey	brown	green
12.) pool	orange	blue

Neutral coloured objects

Object	Top	Bottom
1.) car	red	blue
2.) toothbrush	orange	green
3.) cup	red	yellow
4.) button	green	brown
5.) balloon	orange	red
6.) bicycle	yellow	blue
7.) kite	blue	orange
8.) lorry	blue	red
9.) door	brown	yellow
10.) ball	yellow	brown
11.) sock	green	brown
12.) shirt	orange	green