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PERCEPTION OF BIOLOGICAL MOTION IN AUTISTIC SPECTRUM DISORDER

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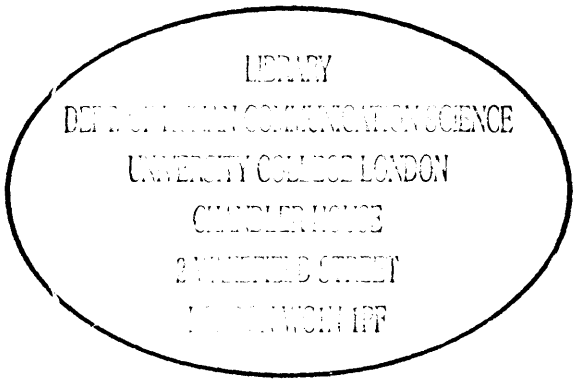

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ABSTRACT

Background: Research has shown individuals with Autistic Spectrum Disorder (ASD) have unusual perceptual skills, particularly with the perception of motion and more specifically biological motion. The importance of perceiving motion can be questioned in relation to developmental of communication skills, which are often impaired in ASD. Two research studies investigating perception of biological motion in ASD have shown conflicting results, therefore more appropriate methods of matching the experimental and control groups was carried out to further investigate the abilities of individuals with ASD to perceive biological motion. **Methods**: A signal detection method was used in which participants identified whether a point-light display was a person or not. Standardised tests were conducted to provide background measures of visuo-spatial and verbal abilities and to investigate whether any of the tests were suitable as predictors of ability to perceive biological motion. **Results**: A comparison between the two groups showed no significant difference in their ability to perceive biological motion, even when the groups were matched for chronological age. A developmental trajectory was established for the biological motion task to evaluate whether the experimental group followed the typical developmental pattern. Again no significant difference was shown between the two groups and none of the standardised tests were found to be appropriate as predictors. **Conclusions**: Although this study has shown no difference between the TD and ASD groups in the perception of biological motion suggesting normal performance of individuals with ASD on the biological motion task, further investigations are required in order to gain a more thorough understanding of a complex area of research.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

INTRODUCTION

Autistic spectrum disorder (ASD) is the collective name of a group of pervasive developmental disorders, including autism and Asperger's syndrome. It is estimated that approximately 535,000 people are diagnosed with ASD in the UK (National Autistic Society, 2006). This project will focus on the perception of biological motion, which is a special form of motion. By understanding how individuals with ASD perceive their environment and others around them, it is hoped that our understanding of the communication difficulties observed in ASD can be increased, with the possibility of developing new diagnostic criteria in the future.

Autism

Leo Kanner, a child psychiatrist at John Hopkins University, first described autism in 1943. The eleven children Kanner described all presented with an inability to relate to others, were unable to convey meaning through language and showed obsessive desire for routine (Ozonoff & Rogers, 2003). Based on these findings and further research, individuals with autism are described as having a triad of impairment (Wing & Gould, 1979; Wing, 1988). These are problems with socialisation, communication and imagination, and have become the basis for diagnosing autism. Current diagnostic criteria are described in the Diagnostic and Statistical Manual (DSM-IV) of the American Psychiatric Association and the International Classification of Diseases (ICD-10) issued by the World Health Organisation (Frith, 2003). Asperger's syndrome, described by Hans Asperger in

1944, shares the characteristics of autism but there is no delay in language development (Ozonoff & Rogers, 2003).

The cause of ASD is still unknown although it is thought to be a developmental disorder with a neurobiological basis of genetic origin (Hill & Frith, 2003). This genetic link affects brain development during the early development of children with ASD (Muhle *et al.*, 2004). There is evidence to suggest that structural abnormalities occur in the brain of individuals with ASD (Bauman & Kemper, 1994), particularly reduced neuronal cell size, increased cell packing density in parts of the limbic system (Bauman & Kemper, 1994), and abnormalities in the cerebellum (Bailey *et al.*, 1998). Non-genetic factors occurring before birth or within the first few years of life, such as viral illness and immunological deficiency, are also suggested as possible factors in the cause (Hill & Frith, 2003). ASD occurs early in development, usually before 3 years old, with a common initial symptom reported by parents to be lack of speech development. A detailed case history then usually shows evidence of difficulties in social responsiveness and early social communicative behaviours, such as eye contact, social referencing, orientation to name, and shared attention (Ozonoff & Rogers, 2003).

Research within ASD has traditionally been directed by three major cognitive theories; theory of mind, central coherence and executive function (Frith & Hill, 2003). It is thought that individuals with ASD fail to acquire a 'theory of mind', and it is believed that this neurologically based deficit in understanding minds is the underlying cause of social communication difficulties seen in ASD (Hill & Frith, 2003). Central coherence is a style of information processing in which

information is processed in context for the gist, putting together all the information. However, people with ASD display a weak central coherence, with an inability to extract global meaning, concentrating more specifically on the finer detail. This can be advantageous when a task requires attention to fine detail, but difficult when a task requires the recognition of global meaning (Happé, 1994; Hill & Frith, 2003). Behavioural problems such as perseveration and rigidity seen in ASD can be explained by the executive dysfunction theory. Executive function includes functions such as planning, inhibition and monitoring of actions, for which there is evidence to suggest that individuals with ASD show deficits in these areas (Hill & Frith, 2003). Recent research has concluded that individuals with ASD have unusual perceptual skills (Bertone *et al.*, 2003; Milne *et al.*, 2002; Spencer *et al.*, 2000). It is hypothesised that this may be due to impairment in the magnocellular visual pathway which results in difficulties perceiving low spatial and high temporal frequency information, for example motion (reviewed in Milne *et al.*, 2005).

Motion perception

Humans constantly use visual information to interpret the world around them, in particular detecting and interpreting the motion and actions of other people (Blake *et al.*, 2003). This perceived motion is interpreted to infer what people are thinking, by observing their body language and facial expressions, and is ultimately the basis of effective communication. Someone can indicate what they are thinking or what their goal or desire is, and what they are referring to whilst they speak by eye movements and head turns (Baron-Cohen *et al.*, 1995; 1997). Individuals with autism, however, often display difficulties with relating to other

people (Kanner, 1943). They have difficulties interpreting actions of other people, particularly with sharing attention, following another person's direction of gaze, and understanding intentions and attitudes (Baron-Cohen, 1991; Frith & Hill, 2003; Swettenham *et al.*, 2003). An explanation for these difficulties could be an underlying impairment in perceiving motion. Therefore the importance of perceiving motion can be questioned in relation to development of communication skills. That is in order to communicate effectively skills such as understanding facial expressions, following gaze and reading facial expressions need to be developed, which they may not if an individual has difficulties perceiving motion, particularly biological motion.

Motion perception in autism

Motion perception has been studied for over 50 years with progress being made in our understanding of the underlying functional anatomy, psychophysical and cognitive factors involved (Milne *et al.*, 2005). However, research concerning autism and motion perception is a relatively new field. Recent research proposes that individuals with autism may have impairment in detecting moving stimuli (Milne *et al.*, 2005). Gepner and colleagues (1995) conducted the first study suggesting such impairment. They found that a group of children with autism were less posturally reactive to visual motion than a control group of typically developing children when presented with optic flow whilst positioned on a force platform (Gepner *et al.*, 1995). In a further study (Gepner & Mestre, 2002) a group of 3 children with autism were particularly impaired in this postural reactivity when the speed of movement was high, however compared to a control group a small group of children with Asperger's syndrome showed increased

postural activity (Gepner *et al.*, 2005). Therefore in individuals with autism visuo-postural coupling is lacking, but a visuo-postural hyper-coupling is seen in individuals with Asperger's syndrome. Gepner and colleagues concluded that this visuo-postural coupling may be an effective marker of autism and may even provide information about the severity of ASD (Gepner *et al.*, 2005).

Sensitivity to coherent motion is another area of motion perception that is being investigated. Coherent motion is a global motion signal evident by integrating locally moving elements (Milne *et al.*, 2005). Sensitivity can be measured by controlling the number of coherently moving local signals within a display of dynamic noise (Milne *et al.*, 2005). It has been reported that children with autism require significantly higher thresholds of motion coherence (Milne *et al.*, 2002; Spencer *et al.*, 2000), and thus have reduced sensitivity to coherent motion (Milne *et al.*, 2005).

Different suggestions regarding the cause of these motion perception difficulties seen in ASD have been made, however at this time there is no definite conclusion. It has been suggested that abnormalities in a specific area of the visual system may be the cause (Milne *et al.*, 2002; Spencer *et al.*, 2000) or that the structural architecture is complete but that there is an inability to integrate complex perceptual information (Bertone *et al.*, 2003). Currently there is no evidence to support either of these suggestions so more research is required in order to develop these theories.

A special type of motion is biological motion, which is a term used to describe any animate movement of biological origin. For example movements of walking, sitting, jumping and running.

Perception of biological motion

Johansson first described biological motion in 1973. Within his study he attached small lights to the joints of human actors, which he then filmed in the dark. This resulted in point-light displays of a small number of moving dots, which observers could identify as human figures (Frith & Wolpert, 2002). Recognition of biological motion has been described as an essential aspect of human evolutionary survival (Pavlova *et al.*, 2001). The point-light displays provide enough information for the observer to tell what action the figure is doing, if the figure is male or female (Barclay *et al.*, 1978; Kozlowski & Cutting, 1977; Mather & Murdoch, 1994), and allow a judgement of emotions to be made (Dittrich *et al.*, 1996).

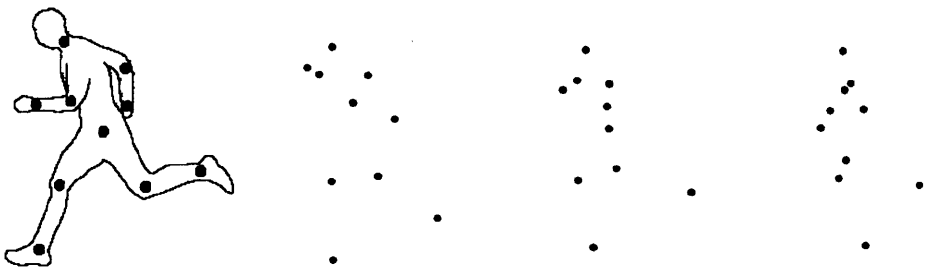

***Figure 1**: An Example of a point light animation sequence. (Adapted from Laboratory for Action Representation and Learning, 2006).*

Perceiving biological motion in point-light displays is thought to be determined by finding the appropriate correspondence between the lights. A single light does not provide enough information to identify an action, but when it is perceived relative to other lights they can be seen as connected (Jordan *et al.*, 2002). For

example, a light on an elbow joint would only be seen as an oscillating light, but when is perceived along with lights on shoulder and wrist joints, the lights are seen as connected in the form of the arm (Jordan *et al.*, 2002). Therefore, the point-light stimulus requires the observer to incorporate the local motion of the individual lights into a global percept of a person (Jordan *et al.*, 2002).

Sensitivity of humans to biological motion is thought to occur early in development of perception (Pavlova *et al.*, 2001). With four month old babies showing a preference to biological motion as opposed to non-biological motion shown in point-light displays (Fox & McDaniel, 1982). Pavlova and colleagues (2001) demonstrated that 3 year old children can recognise point-light displays of human and animal forms, and suggested that this ability develops rapidly reaching a ceiling point at around 5 years old.

Research into the neuronal processes involved in perception of biological motion has proposed a dedicated neuronal system in the brain (Frith & Wolpert, 2002). Single cell studies, along with field potential recordings and functional magnetic resonance imaging (fMRI), have shown specialised visual mechanisms within the superior temporal sulcus (STS) adjacent to the V5 area, which deals with general visual motion (Grossman *et al.*, 2000; Puce & Perret, 2003). These specialised mechanisms produce neuronal responses to images of body movements and process the point-light displays of biological motion (Puce & Perret, 2003), they are able to differentiate between different types of biological motion and interpret the motion (Frith & Wolpert, 2002). It has also been suggested that brain damage within the STS, seen in bilateral parietal patients, can result in difficulties

identifying biological motion when figures are embedded in noise (Schenk & Zihl, 1997). A similar study by Battelli and colleagues (2003) investigated perception of biological motion in unilateral parietal patients. They suggested perception of biological motion relies on high-level description of dynamic patterns, something that is impaired in parietal patients, whilst low-level mechanisms of motion are preserved (Battelli *et al.*, 2003).

Perception of biological motion in autism

There have been two main research studies investigating the perception of biological motion in autism (Blake *et al.*, 2003; Moore *et al.*, 1997). Moore and colleagues (1997) tested children and adolescents' ability to recognise video sequences of point-light displays. Within their research study there were two relevant experiments related to perception of biological motion. One involved the participants discriminating between a walking person and an inanimate object, such as a pair of scissors opening and closing or an ironing board being opened. The video sequences ranged from 40 ms to 5000 ms to establish the exposure time required for the participants to recognise the point-light display. The second experiment required the participant to identify the action being carried out in the point-light display. These actions included clapping, jumping and digging. Moore and colleagues (1997) found that although there were differences between the ASD group and the matched control group, these differences were not significant. Other experiments within the study focused on the recognition of emotions from the point-light displays, which the ASD group did have more difficulties identifying than the control groups (Moore *et al.*, 1997).

It has been suggested that Moore and colleagues study (1997) may not have been sensitive enough to show significant differences between the ASD and control groups (Blake *et al.*, 2003). Other methods of presenting point-light displays have been shown to be more sensitive, such as presenting displays in increasing background noise (Jordan *et al.*, 2002). The use of a behavioural measure to establish difference has also been questioned (Blake *et al.*, 2003). Within Moore and colleagues study (1997) the participants were asked 'what the dots were stuck to' and 'what is the person doing', requiring a verbal response by the child. These responses may have been susceptible to a response bias (Blake *et al.*, 2003) especially as the length of each video sequence was extended each trial so the responses may have been influenced by expectation rather than sensory data (Blake *et al.*, 2003). Blake and colleagues (2003) tackled this response bias by using a signal detection analysis procedure. The participants were presented with a series of 50 sequences of point-light displays of one-second duration. Twenty-five of which were of human action and 25 were scrambled shown in a random order. The participants had to identify whether the sequence was 'a person' or 'not a person' (Blake *et al.*, 2003).

Within this task there was a significant difference in the performance of the group of children with autism compared to the typically developing group, suggesting impairment in perception of biological motion. Blake and co-workers also looked at the correlation between the scores on the task and the severity of autism as determined by the Autism Diagnostic Observation Schedule-Generic (ADOS-G; Lord *et al.*, 2000) and Childhood Autism Rating Scales (CARS; Schopler *et al.*, 1988) scores. The correlation for both scores was significant suggesting a

relationship between the difficulties perceiving biological motion and severity of the autism (Blake *et al.*, 2003). However, the group of children with autism (n=12), aged 8 to 10 years old, had mental ages below that of their chronological age. Therefore the experimental group was matched to a younger group of typically developing children (n=9), aged 5 to 10 years. Although this is a suitable way of matching, there is still a difference between the groups with the experimental group having impairment in mental ability.

Unlike the Moore and co-workers study (1997), Blake and colleagues (2003) also included a non-biological motion perception task in order to obtain a measure of attention levels and motivation. This consisted of a global-form task in which the participants identified a quasi-circular target of eight lines within a quadrant of the display screen. This target could be in any of the quadrants and the precision was varied during the task by introducing 'jitter' to the line orientation (Blake *et al.*, 2003). They described this as a difficult perceptual grouping task that relies on visual mechanisms early in visual processing (Blake *et al.*, 2003). However, this type of control task has limits, and it has been suggested that identification of concentric circles is a relatively easy visual perception task (Bertone *et al.*, 2005).

Aims of the study

The following study will use a similar procedure of that in the study by Blake and colleagues (2003) to further investigate the ability of children with ASD to perceive biological motion, due to the discrepancy of results between the two main studies. A more appropriate matching will be used with the experimental group consisting of children with high functioning autism and Asperger's syndrome and, therefore, no impairment in mental ability. As per Blake and colleagues findings (2003) it is hypothesised that the experimental group, the children with ASD, will have difficulties perceiving biological motion compared to the control group.

A computer program will be used to determine the participants' ability to distinguish between biological motion and scrambled stimuli. Scrambled stimuli are used as the alternative stimulus, as when biological motion is scrambled it no longer resembles biological movement. However, it should not be possible to discriminate the stimuli based on display density or overall movement as this will be controlled for within the computer program. The two groups will be compared and, based on the results of the computer task, a task-specific full development trajectory will be established for the biological motion task in order to evaluate whether the experimental group follows the typical developmental trajectory. This will be achieved by establishing a developmental trajectory (cross-sectional) (Karmiloff-Smith *et al.*, 2004), which will allow a judgement to be made as to whether perception of biological motion develops normally in children with ASD. In comparison to the non-biological motion perception task used by Blake and colleagues (2003) as a control, a number of standardised tests will be used to

provide background measures of visuo-spatial and verbal abilities. Additionally the developmental trajectory approach will be extended to include the standardised tests to determine if any of the tests can be used as predictors for the participants' ability to perceive biological motion. By building developmental trajectory models changes over time can be observed and described in a more comprehensive manner, providing more insight into developmental disorders such as ASD (Karmiloff-Smith *et al.*, 2004).

METHODS

Design

The study consisted of a computer based biological motion task and four tasks from published standardised tests. All participants from the experimental and control groups undertook the biological motion task in order to assess their ability to perceive biological motion. The standardised tests were conducted with the aim of establishing any predictors for the participants' ability to perceive biological motion and to provide background measures of ability.

Participants

Fourteen children, male, with ASD participated in the experiment, aged between 8 years and 4 months and 16 years and 3 months (Table 1). All the children had a diagnosis of an Autistic Spectrum Disorder (ASD) by an appropriate professional, such as a Clinical Psychologist, and all had a Statement of Special Educational Need. The children were recruited from a private residential school for children with ASD and the tasks were carried out within a quiet meeting room at the school, with the participants tested on their own with the experimenter. One participant from the group with ASD did not complete the Benton Judgement of Line Orientation (Benton *et al.*, 1983) due to absence from school as a consequence of illness.

Thirty-four typically developing (TD) children were recruited for the control group within the study (Table 1). The group consisted of both males and females with age ranging from 4 years and 6 months to 12 years and 3 months. The

control group was a mixed group despite the ASD group being male, in order to be representative of typically developing children, whereas ASD is a predominately male disorder, with a male to female ratio of 4:1 for autism, and a possible 15:1 ratio for Asperger syndrome (Frith, 2003). The TD children were all recruited from mainstream schools within the North London area.

Group	Number	Mean age (years:months)	Standard deviation (years:months)	Range (years:months)
ASD	14	12:11	2:07	8:04 – 16:03
TD	34	8:00	2:02	4:06 – 12:03

***Table 1**: Participant charateristics*

The UCL Committee for the Ethics of Non-NHS Human Research approved the research project and parental informed consent was obtained before any participation within the study.

Biological Motion Task

The experimental task in this study was created with visual basic and ran on a Dell Latitude laptop computer. Stimuli were displayed on a 14-inch, flat-panel LCD screen with a viewing distance of approximately 40 cm.

Stimuli

The point-light displays were moving points on a computer screen, generated using video recorded sequences of a person conducting common everyday actions such as running and kicking. A 'Markerless motion-capture' method (Shipley & Brumberg, in review) was used to create the point-light displays, comprising of 13

signal dots attached to the joints of an invisible human figure (1 on the head, 2 on the shoulders, 2 on the elbows, 2 on the hands, 2 on the hips, 2 on the knees and 2 on the feet). The resulting computer display then showed no actor but only the movement of the point-light markers.

To produce the point-light display of a person walking (Johansson, 1973), the figure was presented from a side-view (approximately 6.44° visual angle in height) and remained in the centre of the panel as if walking on the spot. A further four figures were created (running, throwing, kicking and star-jumping) resulting in a set of five in-phase animations. Corresponding out-of-phase scrambled stimuli were created for each of the five actions by taking the trajectory of each dot and playing them temporally out of phase with each other (thus controlling for display density and overall movement). Each animation was presented as white dots on a black panel (17.1° x 17.1° visual angle).

Ten practise items were shown at the beginning of the task (one of each in-phase and scrambled animation type). The first five were presented on the screen until a response was given and the second five were presented for the duration of 1 second. The formal testing consisted of 40 experimental trials (each with a duration of 1 second), which were presented in a random order with constraints such as no more than two of the same action or same phase could appear consecutively.

Procedure

Each participant was shown an example of the point light display and was asked to verify that they could see it was a person walking. They were then informed that during the session they would sometimes see dots that looked like a person and sometimes the dots would "look a bit funny and not really like a person". On the keyboard of the computer used, Y and N stickers covered the z and m keys respectively. Participants were told to press Y if the dots were moving like a person and to press N if they were not. The experimenter controlled the progression of the task by clicking the mouse button to initiate each subsequent trial. Before each trial was presented the experimenter ensured that the child was looking at the centre of the computer screen in order to attend to the trials.

Standardised Tests

All the children were given a diagnostic evaluation including the British Picture Vocabulary Scales (BPVS; Dunn, *et al.*, 1997), the Benton Judgement of Line Orientation task (Benton *et al.*, 1983), and the Pattern Construction and the Copying tasks from the British Ability Scales (BAS II; Elliot, *et al.*, 1996) in order to measure both verbal and visuo-spatial competency and to establish whether any of them could act as predictors for the participants ability to perceive biological motion.

Benton Judgement of Line Orientation Task

Form V of the Benton Judgement of Line Orientation task (Benton *et al.*, 1983) was used within the study. The task was a paper-based task consisting of five practice items and 30 test items presented in a ring bound book. Eleven numbered

lines were displayed in a semi circle at consistent spacing from 0^{o} to 180^{o} on one page. A separate display on a different page showed two of the 11 lines (unnumbered), which were to be identified by the participant. For each practice and test item a display item was shown on the adjacent page. Within the practice items the two lines were complete and identical to those shown in the display item; within the test items only part of the line was shown.

The participants were shown the display of the eleven lines and it was explained that each line had a number. They were then informed that only 2 of the lines would be shown on the next items and they were asked to either say the number of the line or point to the number on the display item. The display item was held at approximately 45^{o} angle for the participant to see both the test item and display item. During the practice items the participants were given help as required and any incorrect responses were discussed with the participants. They were then informed that no help could be given during the test items, and the experimenter recorded exactly the responses the participants gave.

British Picture Vocabulary Scales

The British Picture Vocabulary Scales (BPVS) is a receptive vocabulary test and is used with children aged 3 years to 15 years 8 months. The test is an assessment of accuracy and so there was no specified time limit. The child was asked to choose a picture from four possibilities that illustrated the meaning of a word which the experimenter presented orally. There were 14 sets of 12 items within the task, giving a total of 168 stimulus items. From these items a basal and ceiling set was established for each participant. The basal set was the set with the most

responses correct, that is no more than one error. This was found by starting at the set appropriate for the chronological age of the child and, if more than one error was made in that set, testing backwards through the sets until there was no more than one error. The ceiling set was established by testing forwards through the sets from the basal level until eight or more items were incorrect in a set. Details of the test can be found in the BPVS Manual (Dunn, *et al.*, 1997).

Pattern Construction

The Pattern Construction test is a non-verbal subtest of BAS II (Elliot *et al.*, 1996), which measures visuo-spatial abilities of children aged 3 years to 17 years 11 months. The test required the child to make patterns from two-dimensional blocks, and then three-dimensional later in the test, following a target pattern presented in a picture. At the beginning of the test each child was given a few of the blocks to play with in order to familiarise themselves with the blocks. The experimenter then demonstrated the first item in the test and checked the child understood what was expected of them. The test consisted of 7 items using the two-dimensional blocks and 16 items using the three-dimensional blocks. The test was finished when the child either completed the test or when they were unable to construct four items in five consecutive items. The experimenter timed each of the items within the test using a stopwatch.

Copying

The Copying task is a non-verbal subtest of the BAS II (Elliot, *et al.*, 1996). The test measures the visuo-spatial abilities of children aged 3 years 6 months to 7 years 11 months. The participants were given a pencil, eraser, and 20 pieces of A6 paper which they then used to copy the 20 presented items. The items started very simple (for example a straight line) and progressed to more complex geometric figures. There was no time limit for the completion of the task and the participants were able to view the design whilst drawing. See the BAS II manual for a detailed description of the procedure (Elliott *et al.*, 1996).

RESULTS

Standardised Tests

All the children were given a diagnostic evaluation which including the BPVS (Dunn, *et al.*, 1997), the Benton Judgement of Line Orientation task (Benton *et al.*, 1983), and the BAS II Pattern Construction and the Copying tasks (Elliot, *et al.*, 1996) in order to measure both verbal and visuo-spatial abilities. The raw data for both groups is summarised in the appendices.

Benton Judgement of Line Orientation Task

One of the ASD group did not complete the Benton Judgement of Line Orientation task due to absence from school. The total number of correct responses was recorded for each participant. The mean raw score of the ASD group was 23.38 and the mean score of the TD group was 15.77 (Table 2) out of a possible maximum score of 30 (Benton *et al.*, 1983).

Group	Number	Mean score	Standard deviation	Range
ASD	13	23.38	5.03	14-30 (ceiling)
TD	34	15.77	5.77	4-25

Table 2: *Descriptive statistics of Benton Judgement of Line Orientation Task scores.*

In order to compare the ability of the two groups the participants' chronological age was plotted against the scores obtained in the task. Figure 2 displays the scores of the two groups, with the lines indicating the best-fit regression through each group's scores.

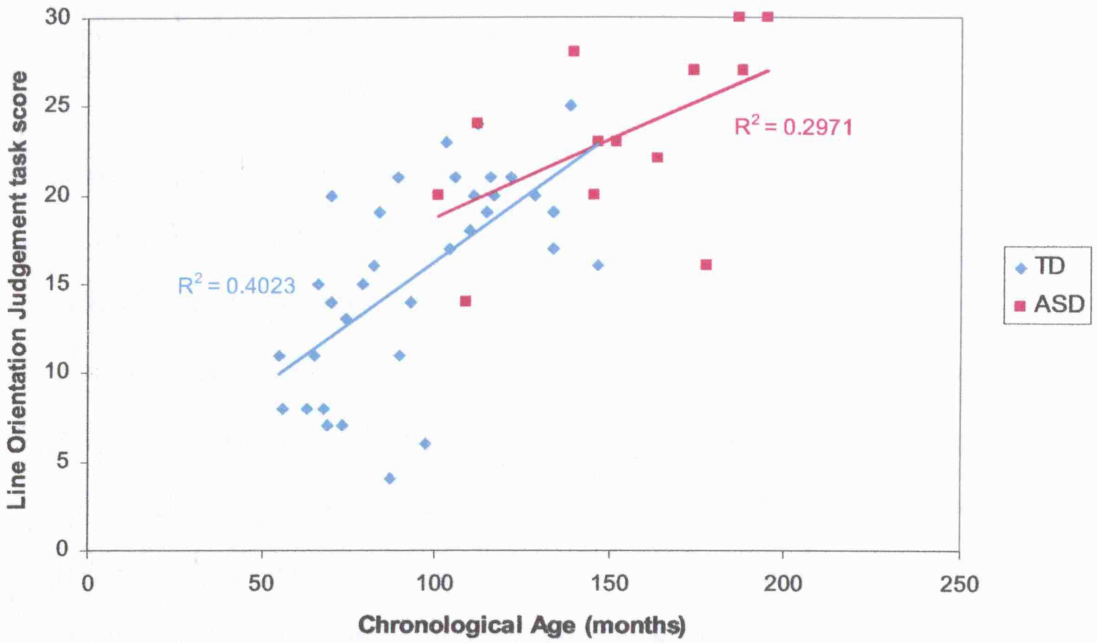

Figure 2: *Benton Judgement of Line Orientation task scores plotted against chronological age for both the TD and ASD groups.*

The graph shows that the ASD group in general obtained higher scores than the TD group, with two participants scoring a maximum (ceiling) score of 30. The R^2 values displayed in Figure 2 indicate the amount of variability of the score that can be predicted from the variability of age, that is the amount of variance accounted for by the trajectory. Therefore approximately 40% of the variability of the TD group can be predicted by age ($R^2 = 0.40$, $F(1, 32) = 21.54$, $p<0.001$), and approximately 30% of the variability of the ASD group can be predicted ($R^2 = 0.30$, $F(1, 11) = 4.65$, $p = 0.054$). Further analysis of the data using analysis of co-variance (ANCOVA) showed no main effect of group ($F(1, 43) = 1.31$, $p = 0.258$) and the interaction between age and group was also not significant ($F(1, 43) = 1.18$, $p = 0.284$). However the main effect of age was shown to be significant ($F(1, 43) = 20.56$, $p<0.001$), this can be seen in Figure 2 as when

chronological age increase so do the scores on the task. Therefore there is no observed difference between the two groups on this task.

British Picture Vocabulary Scales

The raw scores were converted into standard scores, percentile ranks and age equivalence scores using the appropriate age group tables within the BPVS manual (Dunn, *et al.*, 1997). The standard score and percentile rank for one of the ASD group participants, aged 16 years 3 months, were calculated using the age 15:08 table, as this was the highest age group table available in the BPVS manual (Dunn, *et al.*, 1996). The mean test age of the ASD group was 12 years and 7 months and the mean of the control group was 8 years and 5 months (Table 3).

Group	Number	Mean age (years:months)	Standard deviation (years:months)	Range (years:months)
ASD	14	12:07	3:00	7:05-17:00
TD	34	8:05	2:03	4:01-13:00

Table 3: *Descriptive statistics of BPVS age equivalence scores.*

Figure 3 displays the performance of each group in terms of BPVS age equivalence scores plotted against increasing chronological age, again with the lines indicating the best-fit regression.

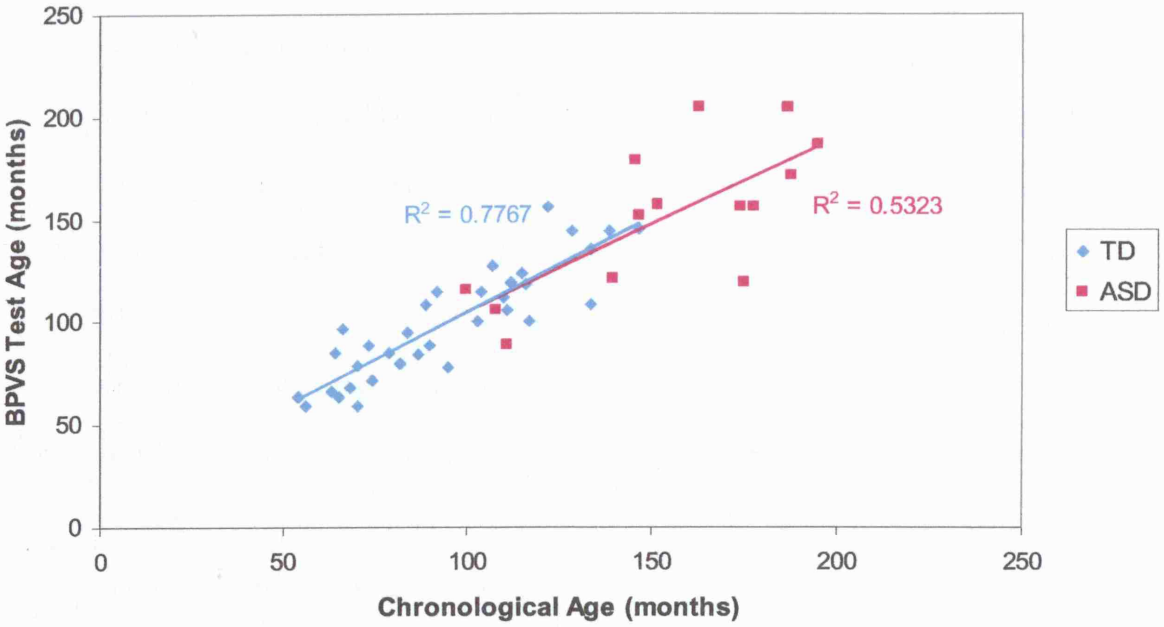

Figure 3: *BPVS test age equivalence scores plotted against chronological age for both the TD and ASD groups.*

It can be seen in Figure 3 that the ASD group achieved higher age equivalence scores than the TD group, however this was probably due to the difference in chronological ages of the groups as the TD group was younger. The R^2 values indicate that the lines account for a great deal of the variability for the two groups, with approximately 78% of the variability of the TD group ($R^2 = 0.78$, $F(1, 32) = 111.29$, $p<0.001$), and 53% of the variability of the ASD group ($R^2 = 0.53$, $F(1, 12) = 13.66$, $p = 0.003$). A distinct overlap of the two lines can be seen and further analysis using ANCOVA indicates a main effect of age ($F(1, 44) = 82.54$, $p<0.001$). However the analysis showed no main effect of group ($F(1, 44) = 0.066$, $p = 0.798$) and the interaction between age and group was also not significant ($F(1, 44) = 0.12$, $p = 0.728$) indicating no difference between the groups in their abilities within this task.

Copying

The raw scores were converted into standard scores, percentile ranks and age equivalence scores using the appropriate age group tables within the BAS II manual (Elliot, *et al.*, 1996). As all the ASD group were above the upper age of the task their standard score and percentile ranks were calculated using the 7:9-7:11 table (as this was the highest age group of the task). The copied drawings were marked following the guidelines of the BAS II manual (Elliot, *et al.*, 1996) for which there were example drawings for each of the score points. The mean test age of the ASD group was 7 years and 1 month and the mean of the TD group was 6 years and 11 months (Table 4).

Group	Number	Mean age (years:months)	Standard deviation (years:months)	Range (years:months)
ASD	14	7:01	1:02	5:04-8:00 (ceiling)
TD	34	6:11	1:03	4:04-8:00 (ceiling)

Table 4: *Descriptive statistics of Copying task age equivalence scores.*

Figure 4 shows the performance of each group in terms of Copying task age equivalence plotted against increasing chronological age, with the lines indicating the best-fit regression

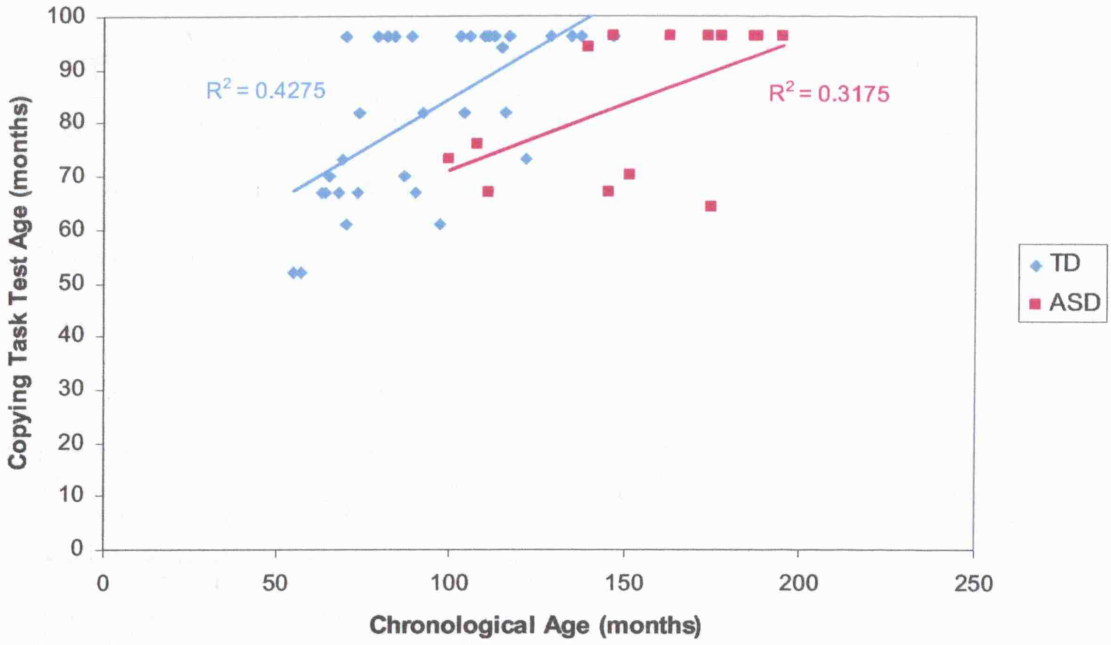

Figure 4: *Copying task age equivalence scores plotted against chronological age for both the TD and ASD groups.*

The R^2 values are lower for the Copying task indicating that the lines account for less variability. 43% of the variability for the TD group ($R^2 = 0.43$, $F(1, 32) = 23.89$, $p<0.001$), and 32% of the ASD group ($R^2 = 0.32$, $F(1, 12) = 5.58$, $p = 0.036$), however a large number of both groups achieved the maximum age equivalence of 96 months, ceiling score, impacting on the R^2 values.

Further statistical analysis of the data using ANCOVA again showed a significant main effect of age ($F(1, 44) = 23.88$, $p<0.001$), but no main effect of group ($F(1, 44) = 0.00$, $p = 0.989$) and no significant interaction between age and group ($F(1, 44) = 1.070$, $p = 0.307$). Therefore the two groups did not differ significantly in their ability within the Copying task, but there was a main effect of age so they differed in their performance with increased age.

Pattern Construction

The raw scores were converted into standard scores, percentile ranks and age equivalence scores using the appropriate age group tables within the BAS II manual (Elliot, *et al.*, 1996). The mean test age of the ASD group was 13 years and 9 months and the mean age of the TD group was 8 years and 3 months (Table 5).

Group	Number	Mean age (years:months)	Standard deviation (years:months)	Range (years:months)
ASD	14	13:09	3:11	5:10-18:00
TD	34	8:03	2:02	5:04-11:03

Table 5: *Descriptive statistics of Pattern Construction task age equivalence scores.*

Figure 5 shows the performance of each group in terms of Pattern Construction task age equivalence plotted against chronological age, with the lines indicating the best-fit regression.

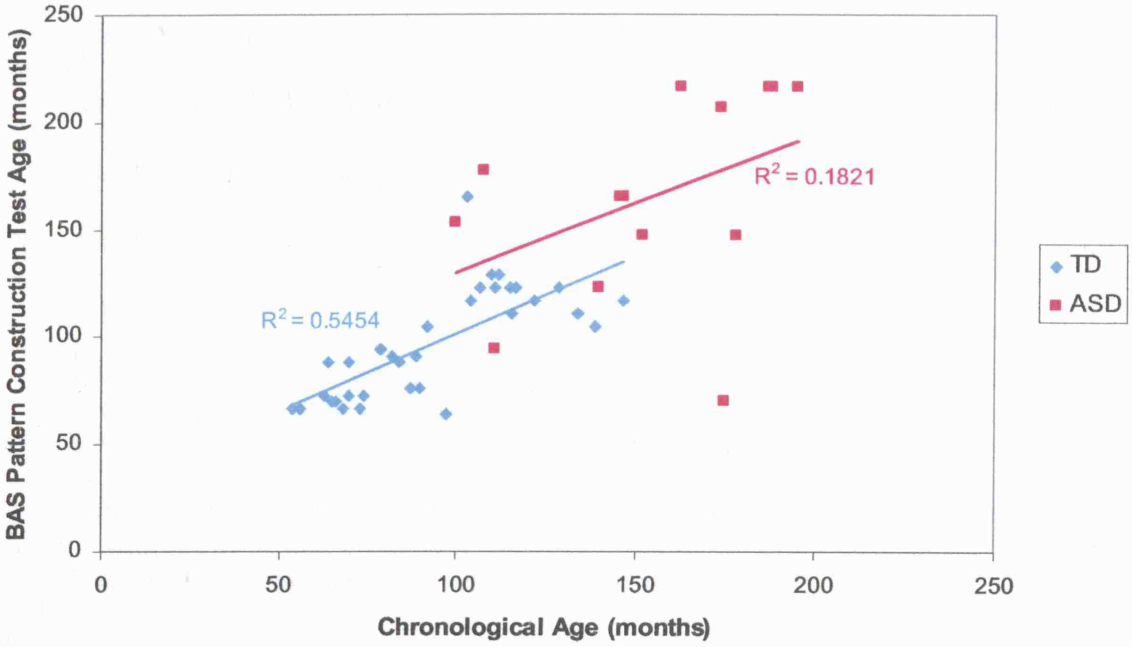

Figure 5: *Pattern Construction task age equivalence scores plotted against chronological age for both the TD and ASD groups.*

The R^2 values show that approximately 55% of the variability can be accounted for by the line for the TD group ($R^2 = 0.55$, $F(1, 32) = 38.39$, $p<0.001$), however only 18% can be accounted for the ASD group ($R^2 = 0.18$, $F(1, 12) = 2.67$, $p = 0.13$).

Similar to the other standardised tests the main effect of age was shown to be significant when statistically analysed using ANCOVA ($F(1, 44) = 20.03$, $p<0.001$). However, no main effect of group was observed ($F(1, 44) = 0.71$, $p = 0.401$) and the interaction between the group and age was not significant ($F(1, 44) = 0.059$, $p = 0.810$).

Biological Motion Task

The raw data from the biological motion computer program was saved in an Excel spreadsheet linked to the program, which was then used to calculate the number of hits, when the participant responded correctly to a biological motion sequence, and false hits, when the participant responded incorrectly pressing yes to a scrambled sequence. These results were then used to calculate the d-prime score, which is an unbiased measure of sensitivity (Blake *et al.*, 2003). D-prime is a measure of the difference between the hit rate and false hit rate, and the larger the difference between the two, the better the participant's sensitivity to the stimuli. Using Excel the calculation used to calculate d-prime is:

D-prime = NORMSINV(hit-rate, 0,1) – NORMSINV(false-alarm-rate, 0,1)

Where NORMSINV is the inverse of the standard normal cumulative distribution, with a mean of zero and a standard deviation of one.

Descriptive statistics of the d-prime results are displayed in Table 6 for both the experimental and control groups (the raw data is summarised in the appendices).

Group	Number	Mean	Standard deviation	Standard error
ASD	14	2.7914	1.50874	0.40323
TD	34	2.0700	1.41860	0.24329

Table 6: *Descriptive statistics of d-prime scores.*

The average d-prime values for the ASD and TD groups are shown in Figure 6.

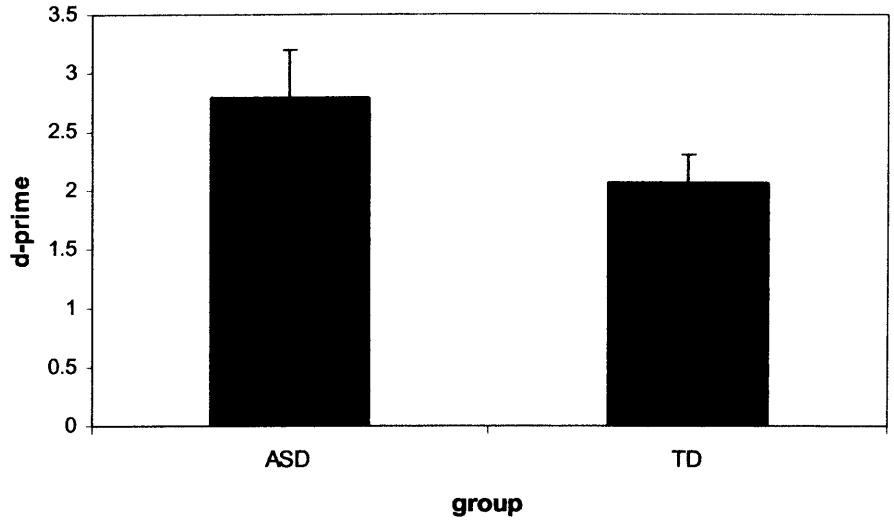

Figure 6: *Bar graph representing the mean d-prime scores for ASD and TD groups with standard error bars*

It can be observed from Figure 6 that the d-prime scores of the two groups are similar with the error bars very slightly overlapping. An independent samples t-test confirmed that the difference between the means of the two groups was not significant ($t = -1.53$, $df = 22.99$, $p = 0.139$).

Figure 6 represents the d-prime scores from the whole of the TD group, however a large number of the TD group are significantly younger than the ASD group which may have had an impact on the mean of the TD scores. Therefore a matched comparison was carried out with the participants from the TD group within the same age range as the ASD group (8 years 4 months to 16 years 3 months for the ASD group and 8 years 7 months to 12 years 3 months for the TD group). Table 7 displays descriptive statistics for the matched d-prime scores.

Group	Number	Mean	Standard deviation	Standard error
ASD	14	2.7914	1.50874	0.40323
TD	15	3.0940	1.10439	0.28515

Table 7: *Descriptive statistics of d-prime scores for the groups matched according to age.*

The mean of the d-prime scores for the groups matched according to age are shown in Figure 7.

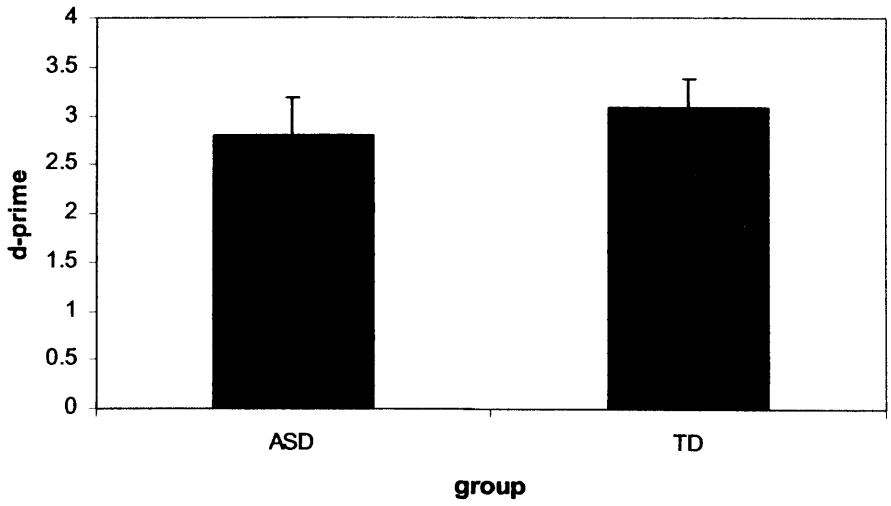

Figure 7: *Bar graph representing the mean d-prime scores for the matched ASD and TD groups according to age, with standard error bars*

Matching the groups resulted in the TD group having a greater mean than the ASD group; however the means remain similar with a distinct overlap of the standard error bars indicating no difference between the groups. An independent t-test confirms the absence of any significant difference ($t = -0.61$, $df = 23.74$, $p = 0.546$).

Developmental trajectories were created by plotting each d-prime score against chronological age. This was first done for the control group to build a trajectory

for typically developing children with age ranging from 4 years and 6 months to 12 years and 3 months. This age range was expected to cover the typical pattern of development of perception of biological motion. A trajectory was then established for the ASD group again using chronological age in order for a direct comparison to be made between the groups. Figure 8 displays the trajectories for the TD and ASD groups, with the lines indicating the best fit regression through each group's data.

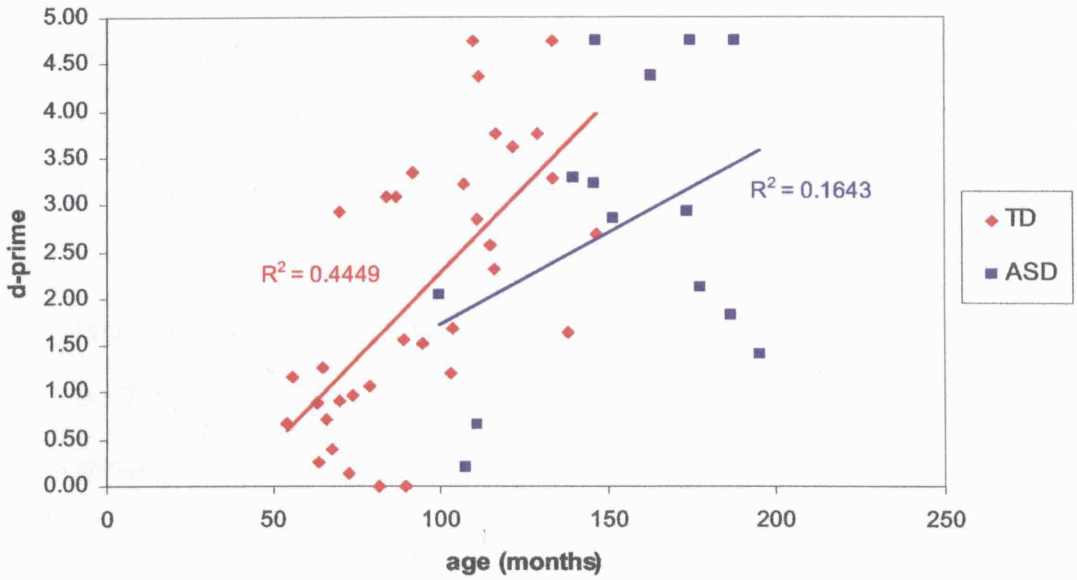

Figure 8: *D-prime scores plotted against chronological age for both the TD and ASD groups.*

The R^2 values displayed in Figure 8 indicate the amount of variability of the d-prime score that can be predicted from the variability of age, that is the amount of variance accounted for by the trajectory. Therefore approximately 45% of the variability of the TD group can be predicted by age ($R^2 = 0.44$, $F(1, 32) = 25.59$, $p<0.001$), however only 16% of the variability of the ASD group can be predicted ($R^2 = 0.16$, $F(1, 12) = 2.36$, $p = 0.15$).

Further analysis of the trajectories using ANCOVA showed no main effect of group ($F(1, 44) = 0.38$, $p = 0.542$) at marginal level. The interaction between age and group was also not significant ($F(1, 44) = 1.602$, $p = 0.212$). Therefore there was no significant difference between the TD and ASD groups in the perception of biological motion determined by d-prime scores.

As previously described there were a large number of the TD group significantly younger than the ASD group. This was to cover any delay that might have been observed within the ASD group, any delayed participants could then be traced back on the TD developmental trajectory. However, as has been shown there is no significant difference between the ASD and the whole of the TD group. Therefore a matched comparison was carried out, with the participants from the TD group within the same age range as the ASD group (8 years 4 months to 16 years 3 months for the ASD group and 8 years 7 months to 12 years 3 months for the TD group). Figure 9 displays the trajectories for the matched TD and ASD groups.

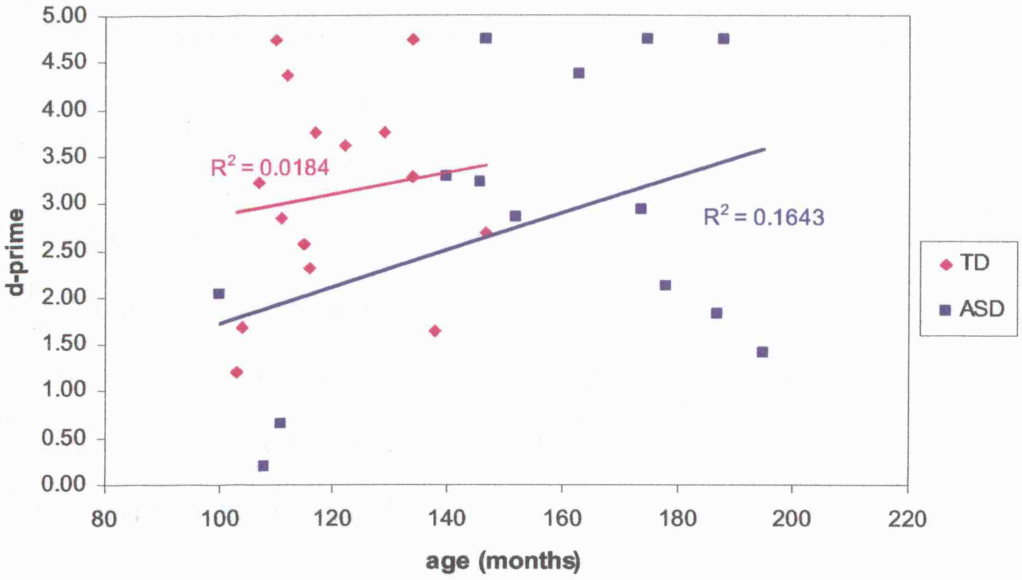

Figure 9: *D-prime scores plotted against chronological age for both the matched TD and ASD groups according to age.*

By matching the age range of the TD group to the ASD group the R^2 value for the TD group dramatically decreased with only 1.8% of the variability being predictable from age (R^2 = 0.018, F (1, 13) = 0.24, p = 0.63),. This can be observed in Figure 9 with the data points being greatly spread around the line of best fit.

Although the ASD trajectory lies below that of the TD trajectory ANCOVA again showed no main effect of group (F (1, 25) = 0.318, p = 0.578) and the interaction between age and group was also not significant (F (1, 25) = 0.094, p = 0.762), due to the great variability of both the groups. Therefore it can again be concluded that there was no significant difference between the ASD and TD groups based on chronological age.

Standardised Tests as Predictors

The standardised tests were explored to see if any were a good predictor of ability to perceive biological motion based on d-prime scores, as well as providing measures of the participants' verbal and visuo-spatial competency. The use of standardised tests would have been more useful if the groups had differed in their performance when measured against chronological age. However, although it was shown that there was no significant difference there was a large variability seen within the ASD group (and also on the reduced age matched TD group), and it may have been that a standardised test was a better predictor than age.

Benton Judgement of Line Orientation Task

Currently the Benton Judgement of Line Orientation task (Benton *et al.*, 1983) has no formal standardisation; therefore raw scores were used rather than age equivalence for the following analysis. Developmental trajectories were created by plotting each d-prime score against the raw score for both the TD and ASD groups, which allowed a comparison to be made. Figure 10 displays the trajectories for the TD and ASD groups, with the lines indicating the best fit regression through each group's data along with the R^2 values.

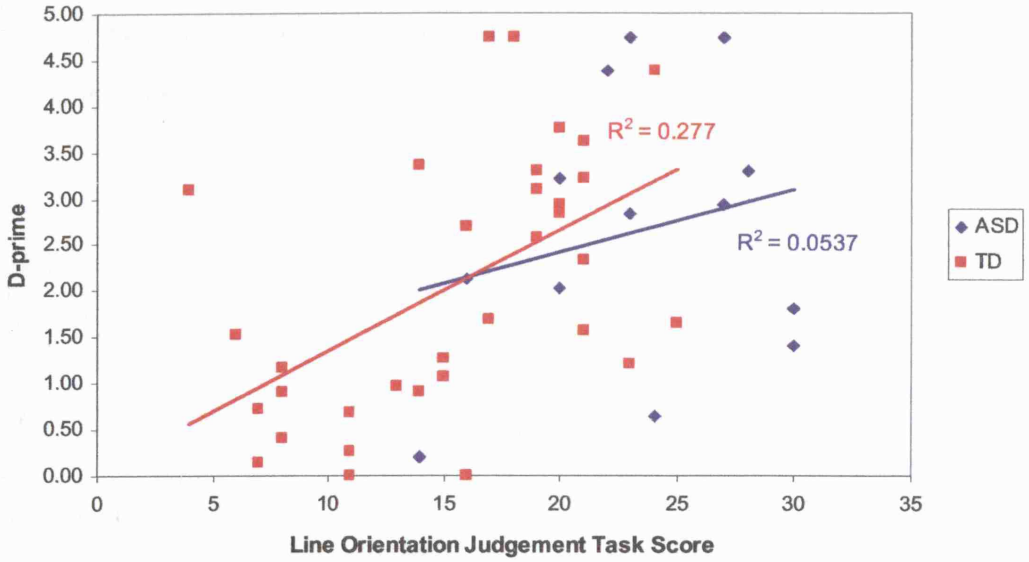

Figure 10: *D-prime scores plotted against Benton Judgement of Line Orientation task score for both the TD and ASD groups.*

Approximately 28% of the variability of the TD group can be predicted by line judgement ability (R^2 = 0.28, F (1, 32) = 12.24, $p<0.01$), and only 5% of the variability of the ASD group can be predicted (R^2 = 0.054, F (1, 11) = 0.63, p = 0.45).

Comparison of the TD and ASD groups using ANCOVA showed that the groups performed similarly and there was no overall group difference (F (1, 43) = 0.29, p = 0.590). The interaction between the Benton Judgement of Line Orientation task scores and group was also not significant (F (1, 43) = 0.56, p = 0.457). Therefore there was no significant difference between the TD and ASD groups in the perception of biological motion determined by the Benton Judgement of Line Orientation task scores.

British Picture Vocabulary Scales

Figure 11 displays developmental trajectories based on age equivalence scores from the BPVS against the d-prime scores.

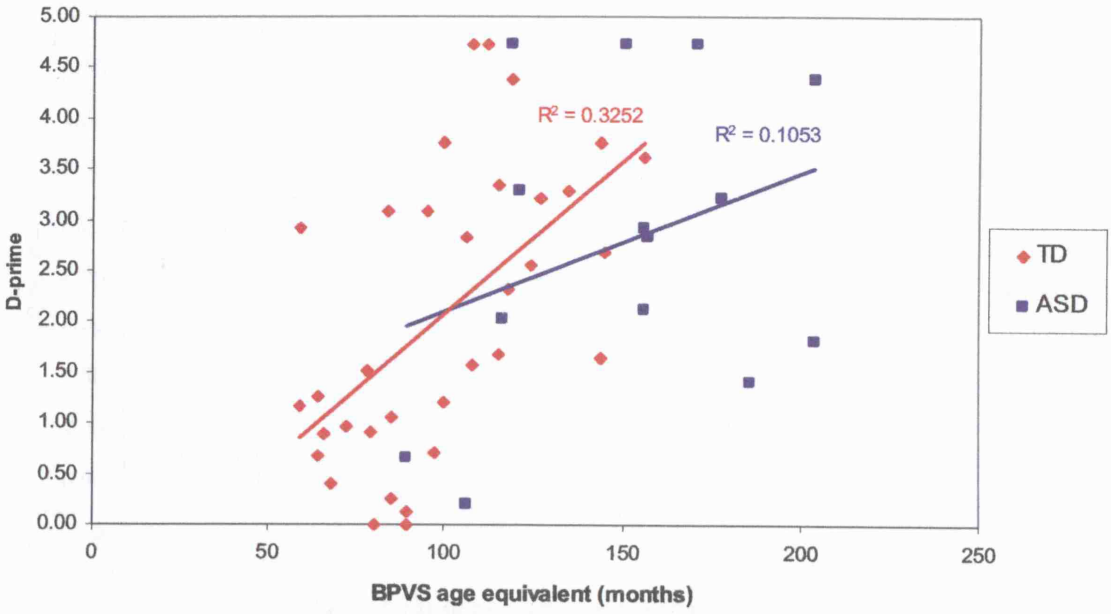

Figure 11: *D-prime scores plotted against BPVS age equivalence scores for both the TD and ASD groups.*

Approximately 32% of the variability of the TD group can be predicted by BPVS age equivalence (R^2 = 0.32, F (1, 32) = 15.37, $p<0.001$), and 10% of the variability of the ASD group can be predicted (R^2 = 0.105, F (1, 12) = 1.412, p = 0.26).

Further analysis using ANCOVA showed no main effect of group (F (1, 44) = 0.91, p = 0.344) and no interaction between BPVS age equivalence and group (F (1, 44) = 1.644, p = 0.206). Therefore there was no significant difference between the TD and ASD groups in the perception of biological motion determined by the test age equivalence based on the BPVS test.

Copying

Figure 12 depicts developmental trajectories based on age equivalence scores from the Copying task against the d-prime scores.

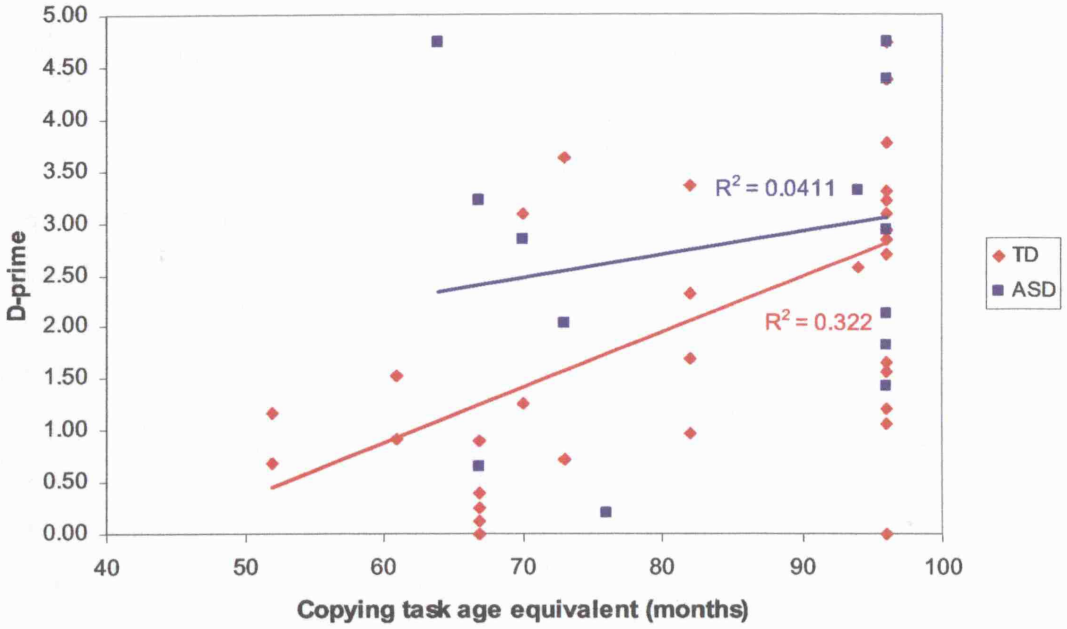

Figure 12: *D-prime scores plotted against Copying task age equivalence scores for both the TD and ASD groups.*

A large number of both the TD and ASD groups achieved ceiling scores on the Copying task, which can be seen by the line of data points at 96 months in Figure 12. Despite this approximately 32% of the variability of the TD group can be predicted by the Copying task age equivalence (R^2 = 0.32, F (1, 32) = 15.22, $p<0.001$), but only 4% of the variability of the ASD group can be predicted (R^2 = 0.041, F (1, 12) = 0.512, p = 0.49). Further analysis using ANCOVA showed no main effect of group (F (1, 44) = 1.62, p = 0.210) and age equivalence in both groups increased at a similar rate (interaction of group and age equivalence: F (1, 44) = 1.080, p = 0.304). Therefore there was no significant difference between

the TD and ASD groups in the perception of biological motion determined by the test age equivalence based on the Copying task.

Pattern Construction

Figure 13 displays developmental trajectories based on age equivalence scores from the Pattern Construction task against the d-prime scores.

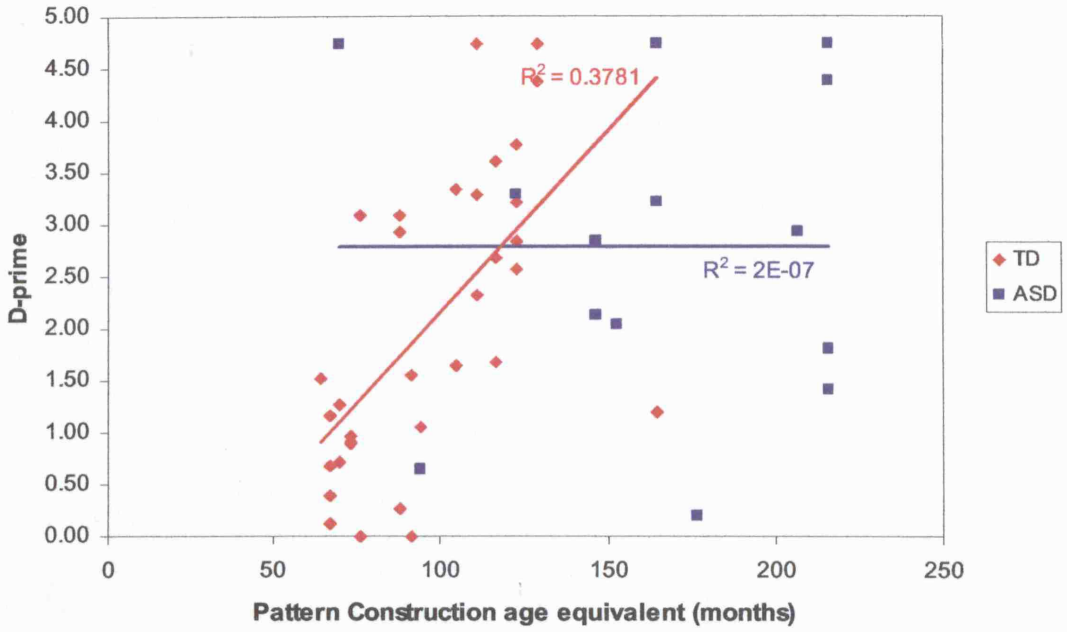

Figure 13: *D-prime scores plotted against Pattern Construction task age equivalence for both the TD and ASD groups.*

Approximately 38% of the variability of the TD group can be predicted by the Pattern Construction task age equivalence (R^2 = 0.378, F (1, 32) = 19.44, $p<0.001$). However, as can be seen in Figure 13 there is a large variability within the ASD group, resulting in a near horizontal line of best fit and none of the variability being predictable (R^2 = 0.000, F (1, 12) = 0.000, p = 0.999).

ANCOVA analysis showed a main effect of group ($F(1, 44) = 6.931$, $p = 0.012$), with the ASD group achieving lower d-prime scores based on Pattern Construction age equivalence, and there was a significant interaction between the group and age equivalence scores ($F(1, 44) = 9.009$, $p = 0.004$). This suggests a significant difference between the two groups based on the Pattern Construction scores; however, as previously discussed there was no relationship observed between the d-prime scores and the Pattern Construction scores.

DISCUSSION

Analysis of results

The purpose of this study was to investigate the ability of individuals with ASD to perceive biological motion compared to a TD control group. It was expected that the ASD group would have difficulties perceiving biological motion within a computer based task using a signal detection analysis procedure similar to that used by Blake and colleagues (2003).

Contrary to the expectations the results showed no significant difference between the ASD and TD groups in perceiving biological motion. These results suggest that the ability of individuals with ASD is not impaired with respect to perceiving biological motion. However a large number of the TD group was significantly younger than the ASD group, which may have had an impact on the average score of the TD group. When a matched comparison was carried out with the participants from the TD group within the same age range as the ASD group, in order to account for chronological age as a factor, no significant difference in performance on the task between the groups was observed.

A task-specific full development trajectory was established for the biological motion task in order to evaluate whether the ASD group followed the typical developmental trajectory. This allowed a judgment to be made as to whether perception of biological motion develops normally in children with ASD. Statistical analysis showed no significant difference between the two groups when comparing both the full TD group and the matched TD group, based on chronological age, with the ASD group. By using a developmental trajectory

approach it was possible to see not only if there was a difference between the groups but also within the groups. It can be seen that there was some variability within the TD group based on chronological age, but the variability in the ASD group was much larger, although this is in line with other studies on developmental disorders (Karmiloff-Smith *et al.*, 2004). This suggests that although there was no significant difference between the groups as a whole there may have been individual differences, which would require further investigation. ASD as the name suggests is a spectrum of disorders and therefore it is important to look at the inter-group variability.

The standardised tests were explored to see if any were a good predictor of ability to perceive biological motion. Raw scores from the Benton Jugement of Line Orientation task and age equivalence scores from the BPVS, Copying task and Pattern Construction task were used to produce the developmental trajectories. Again variability was much greater within the ASD group than the TD in all the tasks, with the TD group showing a general pattern of increase in ability to perceive biological motion based on increased ability in the standardised tests. Within the Benton Jugement of Line Orientation task some of the ASD group achieved higher scores than the TD group, with two participants scoring the maximum score of 30, however it did not apply that these individuals then scored well on the biological perception task. It was expected that the Benton Jugement of Line Orientation task might have been a good predictor of biological perception as both tasks involve visuo-spatial processing. However, statistical analysis showed no significant difference between the groups in perception of biological motion determined by the scores obtained in the Benton Jugement of Line

Orientation task. This was also the case for both the BPVS and Copying task when analysed statistically, with neither task showing significant difference between the groups when using the age equivalence scores to determine the ability to perceive biological motion.

Statistical analysis of the Pattern Construction task results did show a significant difference between the groups with the ASD group achieving lower d-prime scores based on Pattern Construction age equivalence scores, suggesting that this task could be used as a predictor task to assess ability in perception of biological motion. However, regression analysis of the ASD group showed that 0% of the variance could be accounted for by the line of best fit, with no obvious relationship between the d-prime scores and the Pattern Construction scores. For example, one participant in the ASD group obtained an age equivalence of 18 years, above his actual chronological age, and achieved an anticipated good score on the biological motion task, yet another participant obtained a young age equivalence score, below his actual chronological age, and yet obtained a high d-prime score in the biological motion task. Therefore the Pattern Construction task cannot be used as a predictor for ability in biological motion perception, as no linear relationship was observed. This outcome was unexpected as the Pattern Construction and biological motion tasks are both visual tasks processed in similar domains within the brain. It was expected that poor performance in the Pattern Construction task would correspond with poor perception of biological motion.

The standardised tests were also carried out in order to provide background measures of the participants' visuo-spatial and verbal abilities, skills which may have contributed to performance on the experimental task. When the standardised tests were investigated as background measures, it was also found that there was no significant difference between the two groups. Although a main effect of age was seen for all the standardised tests, with an increase in ability with increase in chronological age, no main effect of group was observed and no interaction effects.

No difference was observed between the ASD and the TD groups indicating that there is no impairment in the ability of individuals with ASD to perceive biological motion. As no difference in performance was observed these results support the findings of Moore and co-workers (1997), but this is not consistent with Blake and colleagues (2003) findings, this was despite using a procedure similar to Blake and colleagues (2003). One possible explanation for the difference observed is the level of functioning of the ASD group. Blake and colleagues (2003) recruited a group of ASD participants of lower functioning ability and it may have been that their mental age, which was below that of their chronological age, was the factor for the difficulties observed. One of the intentions of this study was to better match the control and experimental groups for mental abilities to see if this could account for Blake's findings. It has been identified that individuals with non-specific learning difficulties have impairment in perception of specific types of biological motion (Sparrow *et al.*, 1999) and it has been suggested that difficulties in visual motion perception may not be syndrome specific, but in fact related to learning difficulties (Annaz & Karmiloff-

Smith, 2005). Difficulties in perception of motion are seen not only in ASD but also Williams syndrome and Fragile X (Annaz & Karmiloff-Smith, 2005). So therefore this could explain why no difference was seen between the two groups as they were actually matched more appropriately for mental ability, with the ASD group including higher functioning individuals without learning difficulties.

Limitations and Future research

Within this study the participants of the experimental group were grouped together based on a diagnosis of ASD and consisted mainly of participants with high functioning autism or Asperger's syndrome. It has been suggested that there may be a difference in visual processing between individuals with high functioning autism and Asperger's syndrome (Spencer & O'Brien, 2006) and motion perception research has shown a difference between children with autism and Asperger's syndrome (Gepner & Mestre, 2002; Gepner *et al.*, 2005). Therefore as a number of the ASD group had a diagnosis of Asperger's syndrome this may have had an effect on the overall results, which may be another possible explanation for the difference in results between this study and Blake and colleagues (2003). Although not possible within this study due to limited participant numbers, analysis with an experimental group of participants with only autism may produce results more consistent with Blake and colleague's findings (2003). Future research could also investigate the difference in perception of biological motion between individuals with autism and Asperger's syndrome. It may be important to look at the different levels of severity of ASD further investigating the use of severity rating scales (Blake *et al.*, 2003). This could be

done retrospectively using the participants within this study to gain a wider picture of the individuals within the group rather than group ASD as a whole.

It may be that the perception of biological motion is more complex than a yes/no judgement and there may be a higher level of recognition also involved, which is impaired in individuals with ASD, such as perception of emotion. Moore and co-workers (1997) also found no significant difference between the ASD and control groups, but found the ASD group to have more difficulties identifying emotions from point-light displays. These difficulties recognising emotions within biological motion may be an underlying factor impacting on development of communication skills, resulting in the communication difficulties observed in individuals with ASD.

Some participants within the ASD group could describe the process used to make the biological motion stimuli. Explaining to the experimenter how animators such as Pixar use similar computer animation techniques to make films and advertisements. One participant described the animated Toyota advert and the Gollum character in the Lord of the Rings films. This previous knowledge may have resulted in a better than expected performance by the ASD group in their ability to perceive biological motion. A deficit in perception of biological motion would be expected in line with theories of autism such as weak central coherence. If this theory applies to biological motion perception, an individual with ASD would process the individual point lights and not the figure as a whole, focusing on the local detail. However this was not shown in this study. This theory has been discussed in relation to motion coherence and it has been suggested that a

relationship exists between difficulties in detecting coherent motion and weak central coherence (Jarrold & Scott-Samuel, 2005).

Although a comparison based on groups matched for chronological age was carried out, by further extending the group ages for the ASD and TD groups this would allow a full developmental trajectory to be traced highlighting any differences which may occur at any time during development (Annaz & Karmiloff-Smith, 2005; Karmiloff-Smith *et al.*, 2004). The ASD group also only contained male participants whereas the TD group was mixed. Although it was expected that this would have no impact based on the fact that these groups mimic the general populations, further investigations matching the participants based on gender may show a difference between the groups. This could be done retrospectively using the male participants within the TD group of this study.

A signal detection analysis was used in this study, which the participants indicated yes or no to the stimuli. Future studies may want to investigate more sensitive measures, for example analysis of reaction times may show a difference between the two groups. This data was recorded for this study but is yet to be analysed. Other methods of presenting the point-light displays may also provide more sensitive measures. Presenting the displays in increasing background noise has been shown to be more sensitive (Jordan *et al.*, 2002), enabling coherence thresholds to be determined (Reiss *et al.*, 2005).

Although this study has shown no difference between the TD and ASD groups in the perception of biological motion suggesting normal performance of individuals with ASD on the biological motion task, further investigations are required in order to gain a more thorough understanding of a complex area of research.

Word count: 9562

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APPENDIX 1 - TD Group Raw Data

* - data not available

Age	D-prime	Benton	BPVS				Pattern Construction				Copying			
			Raw score	Std score	Age equiv.	Percent-ile	Raw score	Std score	Percent-ile	Age equiv.	Raw score	Std score	Percent-ile	Age equiv.
4,6	0.67	11	54	108	64	70	24	99	93	67	12	79	34	52
4,8	1.16	8	50	103	59	60	23	97	90	67	11	76	31	52
5,3	0.90	8	56	102	66	60	32	108	82	73	21	114	66	67
5,4	0.26	11	72	118	85	89	35	113	90	88	21	114	66	67
5,5	1.26	15	64	111	64	76	28	103	76	70	26	119	79	70
5,6	0.72	7	83	126	97	95	13	104	66	70	27	128	82	73
5,8	0.40	8	58	101	68	55	22	96	46	67	24	111	46	67
5,10	0.91	14	68	109	79	73	31	107	58	73	20	99	12	61
5,10	2.93	20	50	92	59	30	35	113	73	88	33	147	97	96
6,1	0.13	7	76	115	89	85	22	96	27	67	25	115	34	67
6,2	0.97	13	61	100	72	50	32	108	54	73	29	133	31	82
6,7	1.06	15	72	105	85	64	21	116	66	94	34	152	*	96
6,10	0.00	16	68	99	80	50	17	114	58	91	20	143	*	96
7,0	3.09	19	81	109	95	73	35	113	54	88	35	161	*	96
7,3	3.09	4	71	97	84	45	15	110	42	76	24	120	*	70
7,5	1.56	21	91	116	108	86	17	114	54	91	34	152	*	96
7,6	0.00	11	76	99	89	50	15	110	38	76	22	116	*	67
7,8	3.34	14	94	116	115	86	25	122	69	105	29	133	*	82
7,11	1.52	6	66	88	78	24	20	92	4	64	21	102	*	61
8,7	1.20	23	85	98	100	45	54	157	99	165	36	168	*	96
8,8	1.68	17	94	106	115	67	30	129	66	117	29	133	*	82
8,11	3.22	21	101	111	127	76	26	132	73	123	33	147	*	96
9,2	4.74	18	93	101	112	55	41	140	84	129	33	147	*	96
9,3	2.84	20	90	97	106	45	37	135	73	123	35	161	*	96
9,4	4.37	24	97	104	119	65	40	139	82	129	36	168	*	96
9,7	2.56	19	100	106	124	67	34	132	58	123	31	139	*	94
9,8	2.32	21	96	102	118	60	30	127	42	111	29	133	*	82
9,9	3.76	20	85	90	100	25	36	134	62	123	32	143	*	96
10,2	3.61	21	117	118	156	90	32	129	38	117	27	128	*	73
10,9	3.76	20	111	108	144	70	33	133	38	123	35	161	*	96
11,2	4.74	17	91	87	108	20	29	127	24	111	36	168	*	96
11,2	3.29	19	106	101	135	55	28	126	24	111	33	147	*	96
11,7	1.64	25	111	103	144	60	25	122	14	105	23	161	*	96
12,3	2.68	16	112	99	145	50	30	129	18	117	23	161	*	96

APPENDIX 2 - ASD Group Raw Data

Age	D-prime	Benton	BPVS				Pattern Construction				Copying			
			Raw score	Std score	Age equiv.	Percent-ile	Raw score	Std score	Percent-ile	Age equiv.	Raw score	Std score	Percent-ile	Age equiv.
8,4	2.03	20	95	109	116	72	49	150	99	153	15	127	21	73
9,0	0.19	14	90	98	106	45	58	163	99	177	16	130	27	76
9,3	0.65	24	76	85	89	16	19	117	27	94	11	117	8	67
11,8	3.29	28	98	90	121	26	37	135	34	123	19	139	50	94
12,2	3.22	20	127	117	178	87	53	156	66	165	10	114	5	67
12,3	4.74	23	115	102	151	55	54	157	69	165	21	147	69	96
12,8	2.84	23	118	104	157	60	48	149	46	147	12	119	12	70
13,7	4.37	22	146	135	204	99	46	194	96	216	22	152	76	96
14,6	2.93	27	117	89	156	24	42	179	79	207	21	147	69	96
14,7	4.74	N/A	97	71	119	3	3	102	1	70	8	109	2	64
14,10	2.12	16	117	87	156	20	27	149	24	147	20	143	62	96
15,7	1.81	30	142	118	204	89	47	200	93	216	24	168	96	96
15,8	4.74	27	124	90	171	26	47	200	93	216	24	168	96	96
16,3	1.41	30	131	101	186	52	50	220	99	216	23	161	90	96