The Development of Visuo-Spatial Perspective Taking Skills in Autism

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Abstract

The ability to take another person's perspective is highly important for social interaction. People with autism have particular difficulty with taking someone else's point of view. This thesis aimed to examine whether people with autism are impaired at visual perspective taking and the processes which underlie this ability and how this could impact on social interaction.

Chapter two examined body representation in children with autism and results showed no significant difference between these and the control groups in regards to performance. Chapter three investigated mental rotation and egocentric spatial transformations in adults with autism compared to typically developing (TD) adults. Results showed that participants with autism were slower but equally accurate in the mental rotation task and slower and less accurate in the egocentric task. Comparisons across tasks suggested that the participants with autism may have general differences in perception compared to typical people. The experiments in Chapter 4 examined level 2 visual perspective taking (VPT2) and the processes which underlie this ability in TD children. The results showed that in typical children VPT2 is driven by the ability to represent bodies from different points of view. Chapter five examined whether children with autism were impaired at VPT2 and whether the same processes predicted this ability in children with and without autism. Results showed that VPT2 in children with autism is predicted by mental rotation ability and not body representation. In the final experiment, level

1 VPT was examined in children with autism. Whilst previous studies have suggested that this ability may be intact in autism, the results of this chapter suggested otherwise. Overall it was found that people with autism have problems in perspective taking which could impact on their social skills.

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The real voyage of discovery consists not in seeking new landscapes, but
in having new eyes.
-Marcel Proust

1 Introduction

Social interaction is an important part of our everyday lives and maintaining social relationships with other people is seen as a high determining factor in how people perceive their quality of life (Gabriel & Bowling, 2004). One key feature of social interaction is the ability to understand another person's point of view. Expressions such as 'put yourself in my position' and 'try and see things my way' highlight the importance of being able to take another person's perspective. When we take into account how a situation may appear to someone else it becomes easier to understand their thoughts and motivations, making it easier to interact with them.

Understanding the perspectives of others is an ability which falls under the umbrella of social cognition. Social cognition refers to a set of processes which allow a person to gain access to a variety of information about other people, including their emotions, character and mental states (Frith & Frith, 2007). Good sociocognitive abilities are essential for social interaction as they provide us with knowledge about other people. Difficulties in social cognition can seriously impact on the ability to interact with other people, as can be seen in the example of autism spectrum disorder (ASD).

Autism is a neurodevelopmental disorder characterised by deficits in social interaction and restricted interests (Wing & Gould, 1979). It is currently defined under the DSM-V as 'a qualitative impairment in social interaction and communication, and restricted or stereotyped patterns of behaviour, interests or activities'. The causes of autism are currently unclear; several explanations for the disorder have been suggested including genetics, neurological differences and cognition (Frith, 2012; Just, Keller, Malave, Kana, & Varma, 2012; Schaaf & Zoghbi, 2011). This thesis will focus upon how cognitive differences in people with autism could contribute towards their difficulties in social interaction. Specifically how problems in seeing things from someone else's point of view could impact on social functioning.

Problems with social cognition are a key deficit in autism and a variety of socio-cognitive abilities have been shown to be impaired in people with the disorder, including eye gaze (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001), face perception (Adolphs, Sears, & Piven, 2001) and emotion recognition (Hobson, Ouston, & Lee, 1988). In particular, there has been a strong focus on the ability to use social reasoning to understand the beliefs and desires of other people, termed Theory of mind (ToM) or mentalising (Abell, Happé, & Frith, 2003; Baron-Cohen, 1995; Baron-Cohen, Leslie, & Frith, 1985; Fletcher et al., 1995; Frith & Frith, 2007; Frith, 2001; Happe, 1995; Senju, 2012). ToM has also been referred to as 'cognitive perspective taking' (Baron-Cohen, 1989) as the ability to tap into the mental states of others makes it possible to understand things from their point of view. It is widely accepted that ToM is impaired in people with autism (Frith, 2001, 2012; Happe, 1995; Senju, 2012). In recent years there has been some attempt to investigate whether difficulties in perspective taking is limited to mental states only, or may also include more visuospatial perspective taking abilities.

Visual perspective taking (VPT) is the ability to put yourself in someone elses place, in order to understand what they can see. When we attempt to see things from someone else's point of view, it is likely that we draw on a variety of different processes. We may consider the position and posture of the other person's body and how it relates to our own, where they are in relation to ourselves or other objects in the environment and what they might be able to see. Thus it is likely that the ability to perform VPT is based on the integration of several different processes, including those of both a social and spatial nature. Whilst it is clear that people with autism struggle with social demands (Frith & Frith, 2007), less is known about their spatial abilties and more generally how spatial abilities may contribute towards perspective taking in both autistic and typical individuals.

The study of autism provides an interesting method of exploring the development of sociocognitive abilities. We can compare people with autism to typically developing (TD) people on a variety of different cognitive processes and look at the differences between groups. This can allow us to pinpoint where in the chain of processes involved in an ability such as ToM that people with autism are impaired. Not only does this advance our knowledge of abnormal socio-cognitive development, but it can also inform us about what the normal path of development for these abilities may be.

This thesis will focus on the processes which may be involved in taking another person's visual perspective and how these could impact on social interaction, in particular how the social, visual and spatial aspects of perspective taking knit together The social aspect of perspective taking refers to the ability to use information about how someone else sees the world in order to interact with them. Being able to understand how someone else views something will help inform the social context and provide cues in social communication. The spatial aspect of perspective taking refers to how we code the position of stimuli in our environment in relation to ourselves or another person. It also houses the processes we use to put ourselves in another place and the reference frames we use to do this. The visual aspect of perspective taking refers to gaining knowledge of how things will visually appear from different points of view. Altogether, we can use these processes in order to understand how other people see the world. For example, a friend is sitting opposite you at breakfast, the sugar is in front of you and the box of cereal is in front of your friend (Figure 1.5). Your friend asks if you have any sugar. If you spatially transform your point of view onto that of your friend (spatial) , you can then infer that visually the cereal box is blocking their line of sight to the sugar (visual) and respond by passing your friend the sugar (social).

It will examine whether an inability to extract information from the bodies and space around us could result in difficulties seeing things from someone else's point of view. This introduction will begin by exploring the different processes that may be involved in visual perspective taking and what is known about them in autism. First it will examine the role of spatial transformations, followed by the contributions of body representation. Subsequently the literature of VPT in autism will be reviewed, presenting evidence for and against impairment in this ability. An attempt of how this thesis will attempt to solve some of the current inconsistences in the literature on VPT in autism will be presented. Finally ToM in typical and autistic individuals will be discussed, considering how VPT and ToM may be related.

1.1 Spatial Transformations

Spatial transformations are the process by which we are able to mentally realign one spatial position with another. We use them to when we want to imagine ourselves or another object at a different point in space. Spatial transformations are used often in everyday interactions, for example you might need to give a friend directions to meet you. To do this you must take into account the direction in which they are facing and their relation to the environment and objects around them (Figure 1.1). Spatial transformations contribute towards visual perspective taking through being the means we use to put ourselves in someone else's place (Yu & Zacks, 2010). The ability to imagine ourselves and other objects at different points in space is likely to be an underlying factor in deciding how things would appear if we were somewhere else.

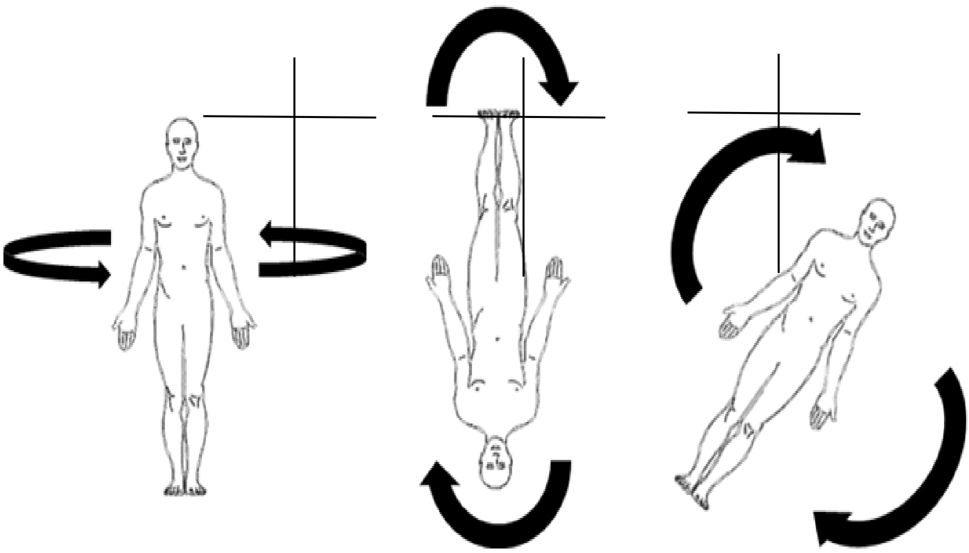

Figure 1.1 Spatial transformations can occur around various planes of rotation (the axis around which a rotation occurs), usually in the 2nd (picture plane) or 3rd dimension (depth plane). Depth plane rotations are based around a central, vertical axis - most often the trunk of an object. They are typically 3D and are the closest rotation to what we experience in everyday life moving around objects and people. Rotations in the depth plane would enable you to see the front, back and sides of an object. Rotations in the picture plane are based around a central vertical axis and the flat surface on which the object is being presented, usually perpendicular to the objects horizontal bisection. For rotations in the picture plane you would typically see a change in an objects top or bottom. These are the types of transformations you may use when you are reading a map

1.1.1 Mental Rotation

Mental rotation (or ‘object based’ transformation) is the process by which we can manipulate the orientation of images in our minds (Shepard & Metzler, 1971; Wraga, Thompson, Alpert, & Kosslyn, 2003) and are able to compare two objects from different viewpoints. It involves mentally transforming an external target/object until it corresponds with another stimulus. Performing mental rotation has been found to elicit a positive linear relationship between reaction time (RT) and angular disparity (Shepard & Metzler, 1971). In the classic study by Shepard and Metzler (1971) participants were presented with pairs of 3D geometric shapes shown at different orientations and asked to decide whether they were the same or different (Figure 1.2). They found that the greater the angular disparity between the two shapes, the longer it took participants to judge whether they were the same. It was argued that this relationship indicates that the time taken to perform mental rotation is comparable to the time it would take to physically transform an objects position. The study has been replicated many times since, and the same results have been found using a variety of different stimuli (Kosslyn, DiGirolamo, Thompson, & Alpert, 1998; Soulieres, Zeffiro, Girard, & Mottron, 2011), such as hands and letters.

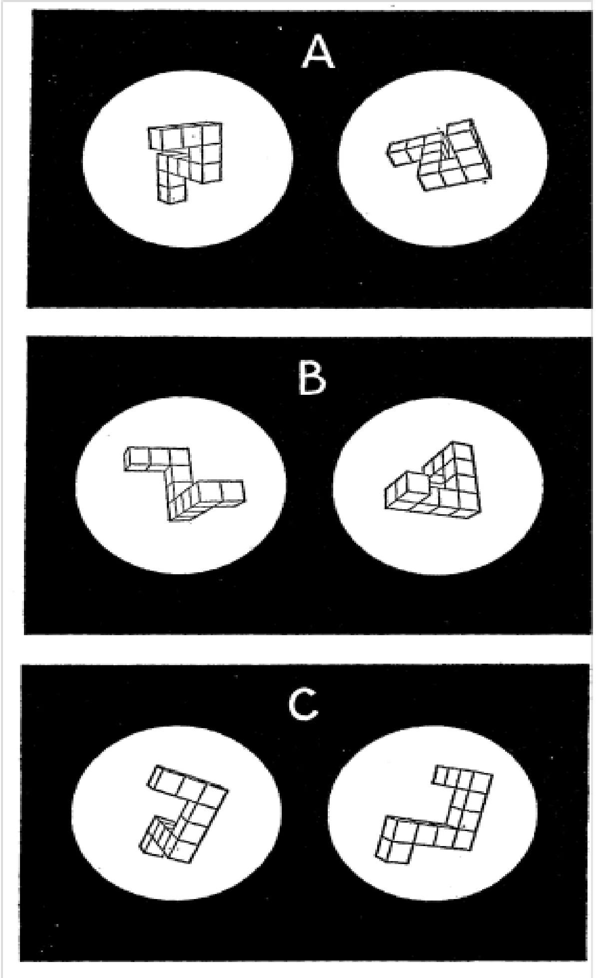

Figure 1.2 Example of the stimuli used in Shepard and Metzler's 1971 Mental Rotation task

Mental rotation relies upon the use of configural processing, though other cognitive strategies are available. There are three stages outlined for completion of configural mental rotation (Just & Carpenter, 1985). First a search is conducted for potentially matching parts between the stimulus and the target, and then the stimulus is mentally rotated as a whole into alignment with its partner. Finally they are compared in order to confirm an accurate judgement (Just & Carpenter, 1985). Another possible strategy for mental rotation is using comparisons of orientation-free surface features. Surface features are parts of the stimulus which are not affected by orientation, such as the location of a limb on a body. This type of processing relies upon coding the relationship between features on one object and then comparing this relationship on the second object to see if it corresponds. It has been referred to as a ‘non-rotational’ strategy (Falter, Plaisted, & Davis, 2008; Just & Carpenter, 1985) as it draws upon the use of features which are not affected by performing the rotation. This strategy does not lead to the classic linear relationship between angular disparity and RT and has been found to be a less efficient strategy overall, leading to slower response times (though no differences in accuracy have been shown) (Just & Carpenter, 1985).

1.1.2 Mental Rotation in Autism

Several studies have shown that people with autism are unimpaired at performing mental rotation (Falter, et al., 2008; Hamilton, Brindley, & Frith, 2009). Hamilton et al. presented typically developing and autistic children with a toy on a turntable which was then covered with an opaque pot and rotated to a different orientation. Children were asked to predict which view of the toy they would see once the pot was lifted. They found that children with autism performed similarly to a group of children with a close chronological age (CA) and better than typically developing children of a similar verbal mental age (VMA). This suggests that the ability to perform mental rotation is intact in autism.

However, evidence for intact mental rotation in autism is not so clear cut in other studies. Falter et al (2008) conducted a replication of Shepard and Metzler's 1971 mental rotation task on typical and ASD children. They found that children with autism were quicker to make the initial decision about whether two stimuli were the same or different than age matched typical children. However, their findings also suggested that participants with ASD were relying more on the use of the surface features in order to perform a match, as opposed to performing a full rotation. This makes it hard to conclude whether people with autism are passing mental rotation tasks based on good mental rotation ability, or are passing based on the use of a non-mental rotation strategy (such as the use of surface features). The latter would suggest that people with autism could still show spatial difficulties in the face of passing mental rotation tasks. Further support for reliance on surface feature processing in ASD comes from Soulieres, et al. (2011), who examined mental rotation of geometric shapes, hands and letters in adults with ASD. They found that autistic participants showed faster and more accurate performance than TD participants on all stimulus types. However, results also suggested that the participants with ASD had used the surface features of the stimuli during the task as opposed to performing a holistic rotation.

Particular reliance on the use of surface features in people with autism has been related to an inability to draw together multiple sources of information to construct a context (Frith & Happe, 1994), termed weak central coherence (WCC). Instead of forming configural representations of a stimulus, people with ASD focus on individual features. Weak central coherence theory was proposed by Frith and Happe (1994) to account for the non-social difficulties present in autism.

Evidence for this theory comes from research showing that people with autism exhibit better performance than typically developing individuals on the embedded figures task (Shah & Frith, 1993). In this task participants are presented with an image in which there may be several shapes embedded, for example, a pushchair may also have a pentagon shaped hood and circular wheels (Figure 1.3). Participants must identify the embedded shapes in order to complete the task. People with autism focus on the fine detail and individual features of a stimulus, as opposed to processing it configurally, making it easier to pick out the embedded shapes (Hill & Frith, 2003; Shah & Frith, 1993). WCC would suggest that people with autism are more likely to use a feature-based processing strategy when performing mental rotation.

Figure 1.3 Example of the an embedded figures stimulus taken from Happé (1999)

The evidence from Falter, et al. (2008) and Soulieres, et al. (2011) suggest that this may be the case, however more research is needed to pin down specific differences in mental rotation in autism.

In summary it is unclear whether people with autism are impaired at mental rotation itself. Though they are able to perform mental rotation tasks, evidence is mixed as to whether they are actually performing a rotation or relying on a different strategy. Chapter 3 will examine mental rotation ability in adults with autism compared to TD adults in order to try and provide an answer to this question.

1.1.3 Egocentric Transformations

Egocentric transformations are the process we use to mentally transform our body from its current position to a different position in space. This is done by mentally realigning the body and its current position with that of a new target. They are often referred to as ‘self-based’ transformations or ‘perspective transformations’ as they involve transforming to a different perspective from the one currently occupied (Steggemann, Engbert, & Weigelt, 2011). Egocentric transformations act as a step in the completion of VPT, as we begin by aligning ourselves with a different position in space. Once there we can decide how things would look to someone else (Yu & Zacks, 2010).

There has been a substantial amount of research into how people perform egocentric transformations. One of the most common methods for examining this ability is to use paradigms which require participants to make laterality judgements. It is thought laterality judgements induce the use of a self-based reference frame as a person can code the position of stimuli in relation to their own left and right (Parsons, 1987). Parsons (1987) studied egocentric transformations by showing participants images of bodies rotated in the depth plane (Figure 1.1) with one arm extended and asking them to decide whether it was a left/right arm (Figure 1.4).

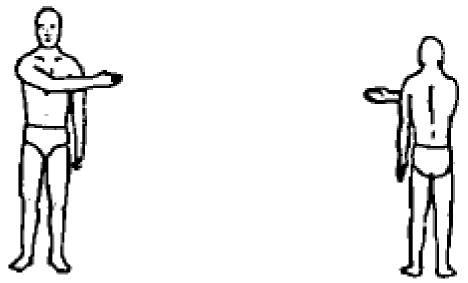

Figure 1.4 Example of the stimuli used in Parsons' 1987 Egocentric transformations task

He found that participants showed a linear increase in response times as the body on the screen rotated further away from the participants own body position (a larger angular disparity between the viewer and target). Parsons suggested that this was because the participant was mentally transforming their own body to match that of the target. The larger the disparity between the body of the viewer and target body the longer the transformation would take. These results have been replicated in a number of studies since (Kozhevnikov, Motes, Rasch, & Blajenkova, 2006; Schwabe, Lenggenhager, & Blanke, 2009;

Wraga, Shephard, Church, Inati, & Kosslyn, 2005; Zacks, Rypma, Gabrieli, Tversky, & Glover, 1999; Zacks, Vettel, & Michelon, 2003). Zacks and colleagues have used a similar paradigm to Parsons to investigate egocentric transformations (Yu & Zacks, 2010; Zacks & Michelon, 2005; Zacks, Michelon, Vettel, & Ojemann, 2004; Zacks, Mires, Tversky, & Hazeltine, 2000; Zacks, Ollinger, Sheridan, & Tversky, 2002; Zacks, et al., 1999; Zacks & Tversky, 2005; Zacks, et al., 2003). Zacks presented participants with images of bodies with one arm extended at varying angular disparities. Participants were required to decide whether the extended arm was a left or right arm. Consistent with Parsons, Zacks found a linear relationship between angle of disparity and response time when bodies were presented in the depth plane. The results of these studies show that the less congruent the body of the participant is with the target, the longer the egocentric transformation will take. This suggests that in order to complete an egocentric transformation, the participant rotates their body as a whole into alignment with the target. The use of one's own personal, whole body schema makes egocentric transformations a highly embodied process.

Embodied cognition is the process by which we use our own body as a template for understanding other bodies. When we perform an egocentric transformation, we begin by creating a motor representation of the target posture and then mentally transforming ourselves (our whole body) until we match it (Grush, 2004). The relationship between angular disparity and response times in egocentric transformations supports this notion (Parsons, 1987), as it provides evidence for the occurrence of a full body rotation. Further evidence for embodied egocentric transformations was found by Schwabe et al. (2009), who asked participants to imagine themselves rotating into the place of an avatar on a screen whose arm was extended. Once participants had performed the rotation they had to make a laterality judgement. The authors found that response time increased with angular disparity between the participant and the avatar, supporting the notion that the participant was performing an imagined whole body transformation. Kozhevnikov and Hegarty (2001) asked participants to imagine themselves placed on a map displaying various landmarks and then make a judgement about the direction of one of the landmarks (i.e. 'imagine you are stood at the traffic light facing the fire station. Point to the tree'). The participant indicated the direction in which they would point by drawing a line on the map. Participants were not allowed to rotate the map, but had to imagine themselves rotating to the various positions. The authors found that accuracy decreased the further the position of the landmark was from the current imagined position of the participant. All of these studies showing a linear relationship between response time and angular disparity provide evidence for the full body transformation involved in egocentric transformations.

In addition, evidence to support embodied egocentric transformations is found in literature which has shown that body posture affects response time. Kessler and Thomson (2009) found that manipulating the posture of participants to be more or less like the target body affected response times. Participants were presented with images of a human avatar seated at a table with an item to either side of them (a flower and a gun). The position of the avatar at the table was rotated to be more or less congruent with the position of the participant (providing changes in the angular disparity between the avatar and viewer). Participants had to make laterality judgements in regards to the placements of the items from the avatars viewpoint. The authors found that the more incongruent the posture of the avatar and the viewer, the longer participants took to respond. These findings show that participants appear to be using their whole body as a template for putting themselves in another place.

Embodied egocentric transformations are also constrained by the way in which the human body can move. Studies of egocentric transformations have shown that when participants are presented with rotations which put the body in awkward or impossible position, response times increase accordingly (Creem, Wraga, & Proffitt, 2001; Petit & Harris, 2005). These studies show that participants find it difficult to imagine the body moving into unnatural positions.

As well as the relationship between angular disparity and response time, studies into egocentric transformations have also shown that using bodies as stimuli decreases response times compared to the use of non-human images. By presenting participants with a body they are instantly able to map their body onto that of the target, making it easier to perform the transformation. Zacks and Tversky (2005) found that participants were quicker to perform laterality judgements for bodies than for objects, suggesting that the very presence of a body in an egocentric transformation facilitates a quicker response in TD people. These studies together show the importance of the body and the use of embodiment in egocentric transformations in TD people.

1.1.4 Egocentric Transformations in Autism

As previous research has shown people with autism to exhibit difficulty with perspective taking (Hamilton, et al., 2009; Yirmiya, Sigman, & Zacks, 1994), it is of particular concern as to whether the underlying spatial mechanisms that drive this ability are intact. Difficulty with using the self as a reference frame could lead to problems with performing the underlying perspective transformation needed to perform VPT.

Currently, very little is known about egocentric spatial transformations in people with ASD. Research *has* highlighted the relationship between social skills and ability to perform egocentric transformations (Brunye et al., 2012; Kessler & Wang, 2012; Shelton, Clements-Stephens, Lam, Pak, & Murray, 2012). Kessler and Wang (2012) found that typically developing participants who scored higher on the Autism Quotient (AQ) (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001), a measure of autistic traits, found it more difficult to perform egocentric transformations. These findings were also replicated by Brunye, et al. (2012). Shelton, et al. (2012) also found a link between spatial skills and social ability. Their study showed that when participants were asked to predict what a spatial array would look like to another person, participants with better social skills (also measured by the AQ) were more accurate. These results suggest that people with poorer social skills (such as people with autism) may find it difficult to use an embodied reference frame.

Evidence for difficulty using the self as a reference frame in autism comes from Carmody, Kaplan, and Gaydos (2001), who found that children with autism showed issues in proprioception that made it difficult for them to estimate where their body was in space. This interfered with performing certain motor tasks (such as catching a ball) because the position of their body was incongruent with where they felt their body was in space. Eigsti (2013) argues for a deficit in embodiment in ASD based upon difficulties in several domains, including imitation, mimicry and movement (these will be discussed further in the section on body representation), however there has been no direct testing of a general embodiment impairment. Chapter 4 will examine egocentric transformations of bodies using a task designed to elicit the use of an embodied reference frame. This will provide some evidence as to whether people with autism can use embodied cognition in spatial tasks.

In summary, the evidence presented suggests that egocentric transformations are an important component of VPT ability, as they allow us to put ourselves in a different point in space using the self as a reference frame. Mental rotation, whilst a good measure of general spatial skills, can be completed without any reference to the self or other people. Yu and Zacks (2010) provided evidence for this distinction, showing that whilst egocentric transformations were likely to induce perspective taking, mental rotation did not. Whilst there is some evidence that people with autism are able to perform mental rotation, there is little investigation into egocentric transformations in the disorder. Chapter 4 will examine both egocentric transformations and mental rotation in TD and autistic individuals in order to try and tease apart any differences in performance.

1.2 Body Representation

The ability to see things from another person's point of view relies to some degree on the ability to identify and represent bodies. The impact that embodiment has upon egocentric transformations and their use in perspective taking has already been discussed. In order to embody a target, a person must be able to accurately perceive and represent that target. Here I discuss body perception and motor representations and how they may relate to perspective taking.

In itself, the body can be a useful way of conveying social information, for example through the means of body posture and the use of gesture. Body posture can aid social interaction by providing information about other people, for example a hunched posture may indicate sadness (Grammer et al., 2004) whilst gestures act as a means of non-verbal communication, for example waving to say ‘hello’. Body perception and knowledge about other bodies may contribute towards perspective taking by allowing us to form an understanding of how people look and move in space. They are specifically useful in VPT as they provide information about what other people may see (for example, head orientation lets you know which direction a person is looking) and a motor representation of the body is also thought to be the first step in performing an egocentric spatial transformation (Grush, 2004). The section on egocentric transformations and embodiment (*1.1.2*) examines how TD people and people with autism spatially align their own body with that of others. This section will discuss how people with and without autism perceive other bodies and relate them to their own motor representations. I will begin by discussing body perception and what we know about this process in autism, followed by a discussion of posture knowledge and representation, processes linked to the mirror neuron system (MNS).

1.2.1 Body Perception

Typically developing people perceive bodies as a whole, taking into account where the constituent parts (limbs) are located in relation to each other (the configuration), termed ‘configural processing’ (Johnson, Perlmutter, & Trabasso, 1979). When we see a body, activation in the brain makes us aware of the positions of limbs followed by a whole (configural) representation of the body being formed (Peelen &

Downing, 2007). This allows us to identify that what we are seeing is a body and not an object. Whilst TD people are adept at discriminating bodies from other types of stimuli (Pavlova, 2012; Simion, Regolin, & Bulf, 2008) it is unclear whether body perception is normal in people with autism.

Studies which have examined whether body perception is intact in autism have so far shown mixed findings (Ham, Corley, Rajendran, Carletta, & Swanson, 2008; Jones et al., 2011; Reed et al., 2007). This may in part be due to the different methods used to examine how people perceive bodies. One way of examining body perception is to use point light walkers. Point light walkers depict a moving body with points of light at each joint and thus provide only motion information without form (Cutting, 1978). Many studies have shown that typical individuals can judge gender, emotion and even familiarity from seeing point light figures (Kozlowski & Cutting, 1978) however findings in autism are not so clear cut. Blake, Turner, Smoski, Pozdol, and Stone (2003) found poorer performance by children with ASD when discriminating biological motion (human movement) compared to global form recognition ('what stimulus are you seeing?'). Specifically they found that children with ASD were able to discriminate a static object from a cluttered background, but struggled to discriminate humans from non-humans in a point light display. Contrary to these findings, a recent large scale study with well-matched ASD and typical groups found no evidence of impairment in perception of point-light walkers in ASD

(Jones, et al., 2011). The authors compared 89 adolescents with autism to 52 age and IQ matched TD individuals and found that there were no significant differences between groups on biological motion involving point light walkers. They also found that biological motion performance was correlated with ToM ability, in that those who were better at performing ToM were also better at discriminating biological motion. These results suggest that whilst people with autism do not have an issue in body perception using point light displays, the ability to perceive bodies does appear to impact on social cognition. This is consistent with the suggestion that bodies may also be relevant for abilities such as VPT, as they provide the information we use to form a representation of another person prior to transforming ourselves into their place.

Another way to examine body perception is to use posture matching tasks. The body inversion paradigm examines a participant's ability to match bodies from different points of view. Findings in TD individuals show that they find it more difficult to match bodies that are inverted as opposed to upright (Reed, Stone, Bozova, & Tanaka, 2003). Reed, et al. (2007) examined the body inversion effect in people with autism. Here participants had to decide whether two pictures of an upright or inverted (upside down) body, face or house were the same or different. Previous research has shown that typical participants are slower to react when faces and bodies are inverted compared to when they are upright. This is taken as an indication of configural processing as inverting a body or face disrupts the familiar spatial configuration of the features, making it more difficult to process the stimulus as a whole. In Reed's study, typical participants showed an inversion effect, that is, slower reaction times to inverted bodies compared to upright ones whereas adults with ASD did not. This provides initial evidence for atypical configural processing of bodies in adults with ASD, suggesting that they do not use the same configural processing strategy as TD people. However it is difficult to conclude from this study whether body perception is impaired in autism, or is simply different. It has been suggested that a lack of configural processing in body perception may be related to weak central coherence and difficulty processing a stimulus as a global form. Participants with autism may try to match bodies based on the use of surface features, picking out the position of specific limbs and comparing them across stimuli. Further support for difficulties in body perception comes from Ham, et al. (2008) who found children with ASD were impaired at a posture matching task. Children with ASD and a group of age and IQ matched TD children completed a gesture imitation task in which they had to imitate hand/finger positions and a posture matching task similar to that of Goldenberg (1999). Ham's study only used meaningless gestures/postures to eliminate any memory components for familiarity being present in recognition. They found that participants with ASD showed a significant deficit in hand/finger matching as well as posture imitation compared to the TD controls. These results suggest that children with autism may struggle with body perception compared to typical children.

In summary it is unclear whether people with autism are impaired at perceiving bodies. While some studies indicate that they are able to identify bodies and discriminate them from other types of stimuli (Jones, et al., 2011) others show that body perception appears to be abnormal (Ham, et al., 2008; Reed, et al., 2007).

1.2.2 The Mirror System

The term ‘mirror system’ was coined by Rizzolatti and colleagues in 1996 and is the collection of brain regions which are activated when a person performs an action or sees someone else perform an action (Rizzolatti, Fadiga, Gallese, & Fogassi, 1996). The MNS has been linked in particular to the understanding and imitation of actions which convey meaningful information (such as a ‘thumbs up’ gesture) (Rizzolatti & Sinigaglia, 2010). Rizzolatti, et al. (1996) suggest that the MNS encodes both the motor features of an action and the goal of the action, which has been substantiated by several studies. Being able to understand the goal of an action in turn may give a person access to inferences about another person’s mental states (i.e. they are reaching to grab a cup, therefore they must be thirsty) (Oberman & Ramachandran, 2007). The MNS has been argued to contribute towards social cognition through providing a foundation for social imitation of other people (Gallese & Goldman, 1998; Williams, Whiten, Suddendorf, & Perrett, 2001). The ability to interpret and recreate the appropriate body posture or gesture of another person has been argued to be important for social interaction (Oberman & Ramachandran, 2007). By interpreting a person’s gesture correctly we can select the most appropriate social response.

There has been much debate as to the role of the human MNS in autism. The ‘broken mirror theory’ (BMT) claims that the MNS is impaired in people with autism, leading to difficulty mentally simulating the social goals of others (action based or mental states) (Buccino & Amore, 2008; Oberman & Ramachandran, 2007). Research into the validity of this theory has produced varied findings, with evidence for both impaired and intact MNS functioning in people with autism (Hamilton, Brindley, & Frith, 2007; Oberman et al., 2005; Oberman & Ramachandran, 2007). Whilst research suggests that goal understanding functions normally in people with autism (Marsh & Hamilton, 2011), there is some evidence that the ability to imitate is impaired (Hobson & Lee, 1999).

Smith and Bryson found that children with autism struggled to both produce and name gestures when prompted (Smith & Bryson, 1998, 2007). The authors attributed this difficulty to impairment in motor representation, but also suggested that problems with gesture imitation could be linked to perspective taking and an inability to represent postures from different points of view. Ham, et al. (2008) also found gesture imitation to be impaired in autism (alongside posture matching). However this impairment was strongly predicted by visuomotor integration skills, which suggests that the difficulty could be a result of motor execution rather than representation. A review of the literature on imitation in autism concluded that there was strong evidence for a deficit, most likely accounted for by poor self/other mapping, which the author related to mirror neuron functioning (Williams, et al., 2001). However, a more recent study from Hamilton, et al. (2007) which examined gesture imitation in children with ASD found no impairment on several measures of imitation (including goal directed imitation). The authors noted that differences in imitation in autism could not be explained by a simple mirror neuron deficit hypothesis (as goal directed imitation was intact) and that further testing was required to pull apart impairment in different aspects of imitation in ASD. Therefore it is difficult to conclude whether people with autism have a global imitation deficit, or are only impaired at certain imitation tasks.

Evidence from neuroimaging studies may help to shed light on these propositions. A recent review which examined 25 neuroimaging studies (using various methods including fMRI, TMS and EEG) found little evidence to support a global mirror neuron deficit in people with autism (Hamilton, 2013). These findings suggest that though people with autism may have difficulty with aspects of motor representation, a global impairment in mirror neuron functioning is unlikely to explain them. Hamilton (2013) suggested that instead of a deficit in motor representation, it is possible that people with ASD struggle to use social context and prior knowledge (social top down response modulation) in order to imitate. This theory suggests that instead of difficulty with forming a motor representation of a gesture, people with autism are impaired at using the social cues that modulate when to use them. These suggestions may explain why people with autism perform well in some imitation tasks but poorly in others, as the social information available to provide context for the imitation may vary between studies. There is however little research into the validity of this theory so far and so it is difficult to make any strong conclusions based on the evidence at hand.

In summary, evidence for a global MNS deficit in people with autism is unlikely. However, there is evidence to suggest that people with autism have difficulty relating the bodies of others to their own. This could impact on how they understand other people and contribute towards impairment in perspective taking. Chapter 2 will investigate body representation in children with and without ASD.

1.3 Visual Perspective Taking

Visual Perspective Taking (VPT) is the ability to see the world from another person's perspective, taking into account what they see and how they see it (Flavell, 1977). In order to perform VPT successfully a person must draw upon both spatial and social information. The spatial information used in VPT includes the current position of both the viewer and the target and the position of objects in the environment in relation to the self and others (Kessler & Thomson, 2009; Kessler & Wang, 2012; Zacks, et al., 2003). For instance, you are sitting at a table with a friend drinking tea, the sugar pot is on their left hand side and the teapot is oriented with the handle towards your friend. The social information used in VPT involves the simultaneous representation of two differing points of view, taking into account whether someone else can see an object, or how they see that object (Aichhorn, Perner, Kronbichler, Staffen, & Ladurner, 2006). For example, your friend can see the handle of the teapot while you see the spout. By interpreting the spatial relationships between objects in a social framework it becomes possible to form a rich representation of differing viewpoints which are useful in a variety of social tasks.

VPT begins to develop in infancy and this development continues throughout childhood (Acredolo, 1978; Bremner & Bryant, 1977; Flavell, Everett, Croft, & Flavell, 1981). Aspects of VPT have been found to develop relatively early in infants, with 16 month old infants being able to locate an object after a physical perspective shift (Benson & Uzgiris, 1985; Bremner & Bryant, 1977) however, the ability to take a perspective differing to one's own has been found to develop somewhat later. Piaget and Inhelder (1947) presented children with a scene showing three mountains. They were asked to identify which view of the mountains someone standing at a different to themselves would see. The authors found that children up to the age of 10 still made systematic errors in judgement. These results have been replicated since (Flavell, et al., 1981). This slow development begins with the use of an egocentric, or self-referenced perspective, in which the infant's own body and point of view are their only source of information about the outside world

(Bremner, 1978). As children develop and begin to engage in joint activities with others, they become able to use another's gaze referentially (Moll & Tomasello, 2004). This allows for the development of knowledge of what others can and cannot see which can be used to navigate and manipulate the environment around them. VPT provides the basis for moving from simply understanding that others have minds and thoughts differing to one's own, to knowledge that the physical world does not necessarily appear the same to everyone. This in turn allows a person to represent the world that is external to themselves and leads on to the development of more complex spatial capabilities. These representations lead onto to more flexible perspective shifts and finer representations of the world and bodies within it.

There are two different levels of VPT outlined in the literature (Flavell, 1977). VPT level one (VPT1) is the basic ability to judge what a person can and cannot see (i.e. whether an item is occluded from their line of sight). The development of VPT1 marks the period at which children begin to understand that other people see things differently to themselves, for example, knowing that if a toy is behind a parent that they will not see it until they turn around. VPT1 has been measured using a variety of tasks which require children to identify whether an adult can see an item which may/may not be occluded (Flavell, et al., 1981; Masangkay et al., 1974). VPT level two (VPT2) is the ability to understand that two different people viewing a scene or object simultaneously do not necessarily see the same thing (Flavell, 1977).

Tasks measuring VPT2 require a participant to be able to say *how* someone else sees an object or scene, for example, one person sitting at a table may see the back of a cereal box and another might see the front.

The development of VPT skills occur in succession, with VPT1 developing first followed by VPT2 (Flavell, 1977). Currently, it is thought that VPT1 develops between the ages of 18-24 months in typical children (Flavell, et al., 1981; Moll, Carpenter, & Tomasello, 2007; Moll & Tomasello, 2004; Moll & Tomasello, 2006) and VPT2 later at around 4-5 years old (Gzesh & Surber, 1985). However, recent advances in ToM research have shown that by using more implicit measures which are less reliant on language (such as eye tracking) we can find evidence of ToM skills earlier in infancy (Southgate, Senju, & Csibra, 2007). It has been suggested that, like theory of mind, VPT1 may include both an implicit automatic processing route and a more effortful explicit route (Surtees, Butterfill, & Apperly, 2012). Studies of VPT to date have used only explicit measures in their methodology (i.e. asking a child to point to an item or verbally report where someone is looking). It is possible that if implicit measures were used to examine VPT1 we may find that it develops earlier than previously thought.

Recently, efforts have been made to provide a clear distinction between VPT levels 1 and 2. Surtees, Apperly, and Samson (2013) suggested that perspective judgements which require only visual information to be taken into account (VPT1) do not require an egocentric transformation, whereas those which require both visual and spatial

(VPT2) do. It has been suggested that there may be an automatic and implicit route for processing of VPT1, whereas VPT2 demands explicit judgements about what other people can see. (Alloway & Alloway, 2010) presented participants with images of a room in which there was a human avatar and coloured disks on the walls. Participants were asked to judge how many disks they could see or how many the avatar could see. The number of disks visible to the participants and the avatar were not always the same (for example, sometimes the avatar could not see all of the disks), creating perspective congruent and perspective incongruent conditions. The authors found that typical adult's responses were slower and less accurate when the avatar's view was incongruent with their own, suggesting that they implicitly coded the avatar's perspective in a VPT1 task, even when not explicitly asked to take it into account. This implicit coding of another person's perspective is not seen to be present in VPT2. Surtees, et al. (2012) found that participants performing a VPT2 task did not show automatic interference effects when presented with a person viewing a perspective incongruent with their own. Another distinguishing feature between the different levels of VPT is the information required to complete them. It has been suggested that VPT1 is based upon the use of dyadic representations (Warreyn, Roeyers, Oelbandt, & De Groote, 2005). This involves a representation of the relationship between a person and an object independent of the self (i.e. Jim can see the cat). Dyadic representations appear to be based upon the use of eye gaze following and line of sight (Warreyn, et al., 2005). It has been suggested that these abilities are intact in people with autism (Leekam, BaronCohen, Perrett, Milders, & Brown, 1997). VPT2 on the other hand, requires triadic representations, in which the relationship between the self, another and an object is coded (i.e. I can see the cat's tail whereas Jim can see the cat's nose). This ability has been argued to be impaired in people with autism (Leekam, et al., 1997). Thus, it is possible that some aspects of VPT may be intact in autism, whilst others may be impaired.

This is evident in the literature on VPT in autism, with studies showing evidence for both intact/impaired VPT1 and VPT2 (Hamilton, et al., 2009; Hobson, 1984; Leekam, et al., 1997; Leslie & Frith, 1988; Tan & Harris, 1991; Warreyn, et al., 2005; Yirmiya, et al., 1994).

One of the issues in assessing VPT in autism is the variety of methodologies that have been used. It has been suggested that people with autism may find some tasks easier to perform than others (Langdon & Coltheart, 2001) making it difficult to assert whether a lack of impairment is a result of intact VPT skills or the task used. Studies of VPT can be categorised by the types of questions they use (Figure 1.5). Most often studies focus on questions about item appearance ('*turn it so I can see the* ___') or location ('*which side of the person is the counter?*'), as well as viewer or object rotations ('*imagine yourself at the blue side of the table'* versus '*turn it so that you can see the apple'*). Studies which examine VPT1 are most likely to ask questions about line of sight ('*can this person see an object*') rather than questions about the item appearance, which is a level 2 VPT skill (Figure 1.5). Another issue is that VPT levels 1 and 2 appear to rely on different cognitive processes, which could influence performance in autism if the processes underlying one were unimpaired compared the underlying processes in the other. Here I will discuss all studies which have examined VPT in autism and evaluate whether they fall into the category of VPT1 or VPT2.

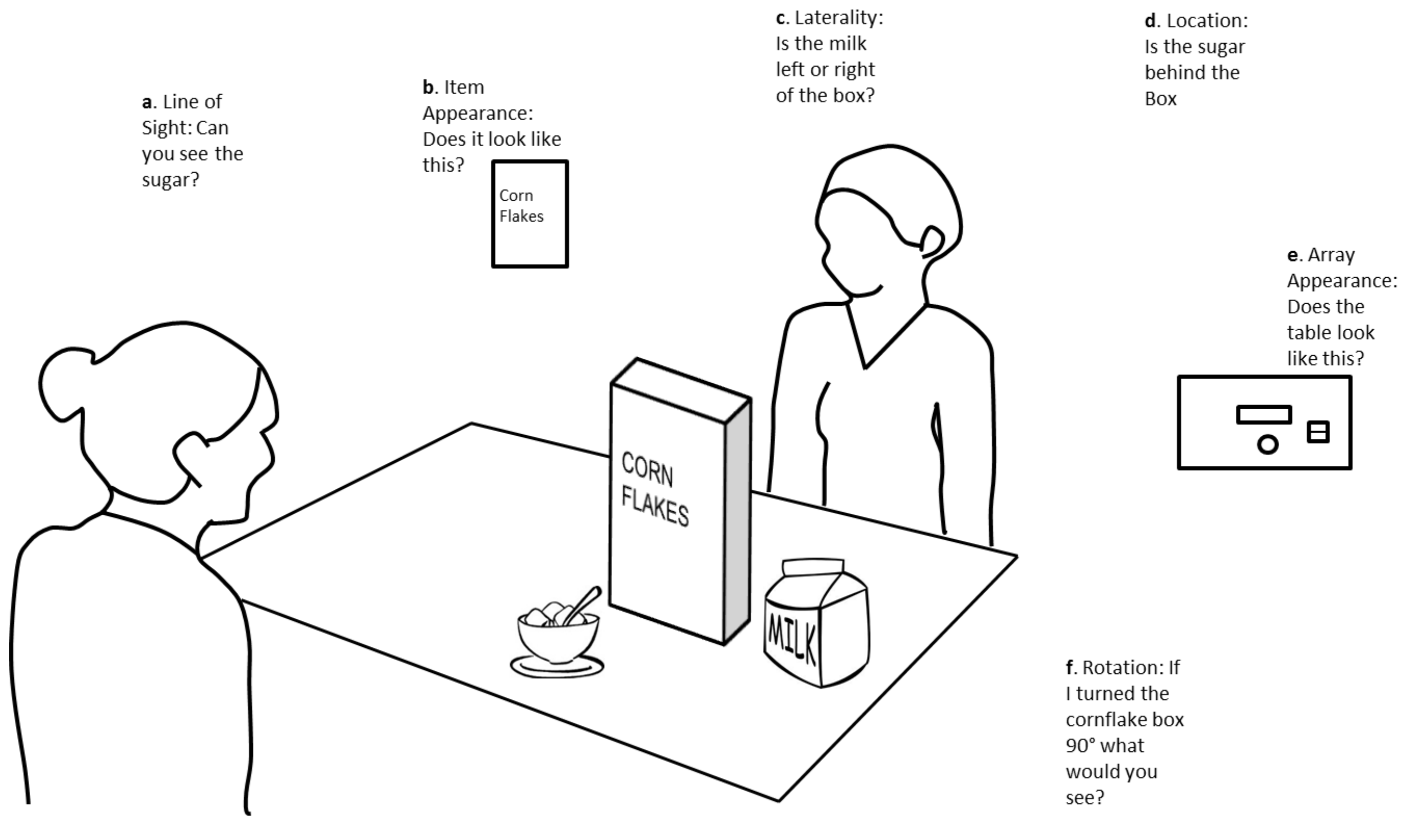

Figure 1.5 Example of different ways in which VPT can be examined. **A**: Line of sight paradigms ask questions about whether a person can see an item, for example, 'can the person on the far side of the table see the sugar bowl?' **B**: Item appearance paradigms ask questions about how an item would appear from different points of view, for instance, 'would the person on the far side of the table see the front of the cereal box?' **C**: Laterality paradigms ask questions about the position of certain items, for instance, 'is the milk to the left or right hand side of the cereal box?' **D**: Item location paradigms ask questions about the prepositional location of items, for instance, 'is the sugar bowl behind the cereal box?' **E**: Array paradigms ask questions about the arrangement of the items in relation to each other-the way in which the array appears. For instance, participants may be shown an arrangement and asked 'does the table look like this?' **F**: Rotation paradigms ask questions about what items would look like if they were rotated to a different orientation, for instance, 'if the cereal box was turned 90°, what would you see?'

1.3.1 VPT in Autism

VPT has often been examined using tasks questioning item visibility (Moll & Tomasello, 2004). In these studies, the child is presented with an item which is either in view or occluded from an adult. The child has to respond to whether the adult can see the item. Explicit studies of item visibility in typical children have shown that they are able to respond accurately from around 2 years old (Moll & Tomasello, 2004; Moll & Tomasello, 2006). Hobson (1984) examined VPT in adolescents with autism and VMA matched TD children using a 'hide and seek' game paradigm, and found that the ability to perform VPT was intact. Participants were presented with a display which included hiding holes and two figures. The participant had to 'hide' their figure from the other, indicating in which hole the figure would need to be placed so that they would not be seen. The participants with autism performed similarly to the ability matched typically developing children. These results have since been replicated using a similar hiding paradigm (Reed, 2002; Reed & Peterson, 1990; Tan & Harris, 1991). The findings from these studies suggest that children with ASD are able to understand the concept of 'hiding' and what other people can see.

VPT has also been examined using line of sight paradigms. Leslie and Frith (1988) used a line of sight paradigm to investigate VPT in children with autism. Participants were presented with a scene in which a doll sat on one side of a cardboard screen and a counter was placed on the same side as the doll, or the opposite side. The child had to respond to whether the doll could see the counter. All of the autistic children were able to complete the task, suggesting that they had a basic understanding of what the doll could and could not see.

Baron-Cohen (1989) used a line of sight paradigm to examine VPT in children with autism and a group of TD children. Children were presented with a task in which an experimenter would orient their gaze or body towards one of six items surrounding the child and the child would have to identify which item they were looking to. The results showed that 92.5% of the children with ASD passed the task compared to 94.4% of TD children, suggesting VPT to be intact in the ASD group. Baron-Cohen's study has been replicated since, though findings have not been quite as clear. Leekam, et al. (1997) compared a group of ASD children to a group of VMA matched typical children on Baron-Cohen's perspective taking task. Though results showed no significant difference between the groups, there was a ceiling effect in the TD group (100%) whereas the ASD group scored on average much lower (66.6%). They also found that VMA was a significant predictor of performance, with those of lower VMA showing more difficulty with the task.

Warreyn, et al. (2005) also conducted a replication of Baron-Cohen (1989) and found that young children with autism performed worse on the VPT task compared to age matched typically developing children. Similarly to Leekam, et al. (1997), they found VMA to be a significant predictor of VPT ability. The authors suggested that VPT may develop later in children with autism and that they may be delayed compared to TD children.

All of the studies presented above (Baron-Cohen, 1989; Hobson, 1984; Leekam, et al., 1997; Leslie & Frith, 1988; Reed, 2002; Reed & Peterson, 1990; Tan & Harris, 1991; Warreyn, et al., 2005) can be classified as Level 1 VPT tasks on the basis that they examine line of sight.

VPT has also been examined using questions about item appearance. Mizuno et al. (2011) used a paradigm similar to that of Masangkay, et al. (1974), in which adults with autism were shown a picture card with two sides. Participants were asked to identify which side they would see or another person would see in two different VPT conditions. In the first condition participants were asked a 'what' question ('*what can I see?*' or '*what can Sarah see?*' versus '*What can you see?*'). In the second condition they were asked a 'who' question (i.e. '*who will see the carrot?*'). Results showed that participants with autism were slower in the 'what' condition than in the 'who' condition. The authors argued that this was a result of difficulty switching between personal pronouns ('what can *you* see?' requires the participant to make the link between 'you' being themselves'), which people with autism often find difficult (Lee, Hobson, & Chiat, 1994). As the study uses a classic VPT1 paradigm, it seems most appropriate to label this a VPT1 task.

Hobson (1984) compared children with autism to a group of younger, VMA matched typical children. To examine VPT, Hobson used an object appearance task in which children had to identify the viewpoint of a third person (a doll). Typical and ASD children were presented with a cube which had a different colour on each vertical face. The child was given a chance to familiarise themselves with the cube. Once familiarised the experimenter would place a doll (Fred) at one side of the cube and ask '*Fred sits here, which colour can he see?'* or *'place Fred so he can see the* ___*'*. The child was then given a second doll (Mary) and asked *to 'put Mary so that Mary sees the same as Fred sees'*. Results showed that there was no significant effect of group, with the ASD children performing similarly to the typical children. Hobson did find a significant effect of verbal ability in the ASD group, with higher functioning ASD children performing better. This is consistent with the findings from Warreyn, et al. (2005) and Leekam, et al. (1997), and suggests that verbal ability may be an important predictor of VPT. It is also worth noting that neither group performed at ceiling level in Hobson's task meaning any group differences should be clear. As the task could be completed using a VPT1 strategy in which participants use line of sight to respond rather than performing a first person transformation it seems appropriate to define this as a level one VPT task.

Reed and Peterson (1990) also examined VPT in children with autism alongside ToM using an item appearance paradigm. Thirteen

ASD children and 13 VMA matched typically developing children were tested on their ability to rotate a familiar item (a toy) so that the experimenter could see a distinct feature (i.e. '*turn it so that I can see the nose'*). Four different toys were presented and children had to score 100% across all four trials to pass. In contrast the cognitive perspective taking task required the children to perform the Sally-Anne Theory of Mind task (Baron-Cohen, et al., 1985). The authors found that the children with autism performed similarly to the typical children in the VPT task, but worse in the cognitive perspective taking task. The authors concluded that it could not be the social aspect of ToM that participants with autism had difficulty with, as the VPT task was also social and that poor ToM may be a result of impaired abstract thinking. These findings suggested that VPT and mentalising are dissociable abilities, with VPT tapping into a different process then ToM. However, the authors found a ceiling effect amongst both the typical and autistic children in the VPT task. This makes it possible that group differences may have been masked due to the task being particularly easy for both groups of participants. This task was classified as a VPT2 task by the authors on the basis that it meets criteria for two people viewing an object from different vantage points (Flavell, et al., 1981). However, participants could also use a basic line of sight (VPT1) strategy (turning the item until the feature (i.e. nose) was in the line of sight of the viewer) to respond. The distinction between level one and two VPT are blurred in this task, and it may be more appropriate to label this a VPT1 task.

Tan and Harris (1991) examined VPT in children with autism using an item location task. Twenty children with autism and 20 VMA matched typically developing children were tested on their ability to identify the view one of two soft dolls would have of a third object (i.e. *which object would John say was 'in front'?*). The authors also measured the children's ToM using a desire understanding task, presenting the children with scenarios in which someone was offered food that they did or did not like. Children had to respond to whether the person would be happy or unhappy with the offer. There was no significant effect of group on either task, with the autistic children performing similarly to the typical children on both VPT and desire understanding. As with Reed and Peterson's task, Tan and Harris also found a ceiling effect across both groups of participants which may have masked any group differences. The authors concluded that a global social deficit in autism is unlikely, and that impairment may be related to process and task specific delays. As this task measures how two people seeing a given object may view it differently due to a change in orientation or location (i.e. for Mary, the pencil is in front of the block, whereas for John the pencil is behind the block) it can be considered a VPT2 task.

Yirmiya, et al. (1994) examined VPT in children with ASD using an object rotation paradigm in which children were presented with familiar item (toys) on a rotating table. The task required both object rotation and item appearance ('how would this look to me'). ASD children were compared to age and IQ matched typically developing children on their ability to turn a turntable containing 3 or 10 items so that it matched the point of view of the experimenter. Children were instructed to ‘turn it around so that you will see it from where you are in the same way that I see it from where I am’ or turn it around until you see it in the exact same way that I see it now from where I am standing’. They found that children with ASD showed a higher number of errors than the typical children. Errors were further categorised into two different types: incorrect (in which the answer was simply wrong) or egocentric (in which the child displayed the turntable with their own point of view). Children with autism were found to display more incorrect errors in the 10 item trials, and more egocentric errors in the 3 item trials. This suggests that the 10 item trials were more reliant on memory, as if both trial types were equated for difficulty you would expect to see similar types of errors across both. This task demands the calculation of two different viewpoints and is clearly a VPT2 task, but as the authors note it has heavy memory demands which may limit performance.

Hamilton, et al. (2009) used a related paradigm to examine VPT, mental rotation and ToM ability in a group of ASD children compared to verbal ability matched typically developing children. Two further groups of TD children were also included in the study, a typical mid-age range group and a typical older group. For the VPT task children were presented with the toy on the turntable and asked to identify their own point of view on the answer sheet. The toy was then covered and a doll placed at another spot on the table. The child was asked to identify the view of the toy the doll would have when the pot was lifted. For the mental rotation task children were shown a toy on a turntable and asked to identify which picture on their answer sheet matched their view. The toy was then covered and rotated and the child asked to identify which view they would see when the pot was lifted. ToM was assessed using a battery of different theory of mind tasks, including diverse desires and the Sally-Anne task (Baron-Cohen, et al., 1985). Results showed that the children with ASD were significantly worse on the VPT trials compared to the typical children, but performed better on the mental rotation task. It was also found that VPT was significantly predicted by ToM score, suggesting mentalising is important for perspective taking. The authors suggested that VPT relies on the same cognitive systems as ToM. This is the only study reviewed which includes both a social and non-social spatial task, as well as a measure of ToM. The task attempts to integrate different task demands (viewer and item rotation, item appearance questions) making it possible to start pinpointing specific difficulties with VPT. The use of a control spatial (non-social) task also allows the authors to make clear conclusions about which aspects of VPT that people with autism find difficult (social as opposed to the spatial). As the task explicitly requires participants to say what one object would look like from two different points of view, with no line of sight information available (the target was covered with a pot), this can be classified as a VPT2 task.

Dawson and Fernald (1987) also examined VPT in children with autism using an object rotation paradigm in which children had to orient an item a certain way for the experimenter to see it. No control group was included in the study. Participants were presented with cards, blocks and various picture and asked to orient it '*so the experimenter could see the face / tail etc...*'. None of the children scored at ceiling level on the task, and performance correlated with social skills, but without a control group it is hard to interpret this data.

David and colleagues (2010) examined VPT and ToM in high functioning adults with Asperger syndrome compared to age and IQ matched typically developing adults. Participants completed two tasks, one examined VPT and the other examined ToM. In the ToM task participants were presented with a virtual image of a person with one item either side of them. The person could be displaying one of three possible body, face and hand postures (positive, neutral or negative) towards one of the objects. An example of a positive hand gesture would be pointing, whereas negative would be holding the hand out with the palm facing forwards (similar to a 'stop' signal). The participant's task was to identify which object the other person desired (mentalising for other) or which they would desire themselves (mentalising for self). In the VPT task the participant was presented with the same image of the person with two objects, one of which was elevated. The participant had to identify which object was elevated from their own point of view, or from that of the other person using a laterality judgement (i.e. the item on *my left* is higher). Measures of speed and accuracy were taken from each participant. In the ToM task results showed that the ASD participants were significantly slower and less accurate at identifying the correct answer when mentalising for other. They were also trending towards slower mentalising for self (as accuracy on this task was subjective accuracy could not be measured). There were no differences found between groups for speed or accuracy in the VPT task, for self or other. The authors acknowledged that the VPT task may have been too easy compared to the mentalising task which may explain differences across tasks. One limitation is that this task does not require participants to take the visual perspective of the other, but only to judge what is on the left or right. Spatial-transformation tasks (Parsons, 1987; Zacks, et al., 1999) require participants to make laterality judgements about an item in relation to another person, but it is not clear if these are the same as VPT tasks. Further research is needed into these paradigms in order to assess where they fall in relation to perspective taking.

Similarly, Zwickel, White, Coniston, Senju, and Frith (2011) examined VPT and ToM in adults with autism and age and IQ matched typically developing adults using a laterality judgement paradigm. In the VPT task participants viewed videos of animated triangles (Castelli, Frith, Happe, & Frith, 2002), and during the videos a dot appeared to the left or right of the triangle. Participants were asked simply '*was the dot on your left or right*'. On incongruent trials a dot on the participant's left fell on the right of the triangle (or vice versa), while on congruent trials a dot on the participant's left was also on the left of the triangle (or both on the right). Critically, this congruency only arises if the triangle is perceived as an animate active creature. Both typical and autistic participants showed a congruency effect in this task, demonstrating that they could spontaneously consider the left/right orientation of an animated shape. However, the autistic participants were less good at judging the mental states of the triangles in the same animations. This is consistent with the findings of David et al. (2010). Like that study, it is not clear if this task truly demands calculation of the *visual perspective* of another agent rather than just their orientation. More research is needed to explore the use of visuo-spatial perspective taking paradigms in autism.

1.3.2 Evaluating VPT in Autism

I have reviewed 13 studies of VPT in autism, and suggest that 7 of these assessed VPT1, 3 assessed VPT2 and 3 were unclear or assessed laterality. Of the 7 studies examining VPT1, 5 report no differences between typical and autistic participants while the other 2 find that participants with autism perform worse than typical participants. Of the 3 studies examining VPT2, 2 report group differences and the third does not.

There are several interesting issues arising from the review of these studies which can guide future research. One important problem is that the boundary between tasks used to VPT levels one and two is not always clear. A task might be intended to assess level 2 VPT but be solved by a level 1 strategy (or vice versa). Some of the tasks used to measure VPT2 could also be completed using a VPT1 line of sight strategy, without performing a first person perspective transformation. This makes it difficult to conclude whether participants are using VPT1 or VPT2 to complete the task.

In my review of the literature I have followed Flavell (1977) and defined VPT1 as the ability to consider what others can and cannot see (i.e. some items we see may be occluded from their sight and vice versa) and VPT2 as the ability to understand that two people viewing the same item may not see it in the same way (i.e. on person may see the front of the item and the other sees the back). Line of sight tasks seem to be the clearest way to assess VPT 1 (Baron-Cohen, 1989; Leekam, et al., 1997; Leslie & Frith, 1988; Warreyn, et al., 2005), while we suggest that item appearance tasks are the best way to assess VPT2 (Hamilton, et al., 2009) see Fig 1.5 a&b.

A second issue is the use of appropriate control tasks to assess children's memory abilities (especially for complex displays) and their abilities to perform spatial transformations. The comparison of an experimental task and a closely matched control task in the method of fine cuts (Frith & Happe, 1994) would allow for close examination of the cognitive components which distinguish the different levels of perspective taking.

Understanding the relationship between VPT2 and ToM is important. Both of these require the consideration that the other person has a different representation to oneself, either a different visual representation or a different belief. However, early studies suggesting that VPT2 is intact in autism while ToM is impaired motivated the idea that it is easy to distinguish visual representations of self and other because VPT2 allows concrete feedback by physically moving to a different location (Leslie, 1987). In contrast, ToM requires more abstract representations which people with ASD find difficult. However, more recent data suggest that VPT2 and ToM are linked in typical children (Hamilton, et al., 2009), in those with specific language impairment (Farrant, Fletcher, & Maybery, 2006) and in the brain (Aichhorn, et al., 2006). This implies that VPT2 and ToM may share similar cognitive mechanisms. Certainly, many false belief tasks rely on the ability to distinguish what people have seen (Sally did not see Anne move the marble). The relationship between these two processes in autism will be examined in Chapter 5.

Another important question concerns how the social and spatial elements of VPT2 fit together: Does intact VPT2 require spatial *and* social information, or could it be done using just one of these. If VPT2 can be completed using social *or* spatial information it makes sense that it can be unimpaired even in the face of significant ToM deficits, as participants' could rely on the use of spatial information to complete a task. However, if VPT2 requires the integration of both spatial and social information to be effective, then even good spatial ability would not completely compensate for poor social processing. Again, if we can conduct more studies which include control measures of abilities such as spatial and social skills, we can start to tease apart where the specific difficulties in some VPT2 tasks comes from in autism. This will also allow for examination of the underlying cognitive mechanisms which subserve VPT and abilities such as ToM. These relationships will be investigated further in Chapter 5.

It has also been suggested that intact VPT level 1 and 2 performance in people with ASD may be reliant on the use of certain paradigms. Langdon and Coltheart (2001) suggested that tasks using questions about item location as in Tan and Harris (1991) were particularly open to completion via spatial cues making it possible for those with social difficulty to perform. The authors also proposed that item appearance questions may be easier to understand than object rotation questions (‘*turn it so that I can see the nose’* versus ‘t*urn it around so that you will see it from where you are in the same way that I see it from where I am*’) as these tasks rely on more simple verbal instructions, suitable for those with a lower verbal ability. These factors are worth taking into account when designing studies to measure VPT as they suggest that the type of task used may easily influence the performance of participants.

There are also issues in the lack of consistency in matching groups. Though some of the studies have used rigorous matching techniques (David, et al., 2010; Hamilton, et al., 2009; Yirmiya, et al., 1994), others took no measure of cognitive ability in their typical participants. Both Reed and Peterson (1990) and Hobson (1984) argue for evidence of unimpaired VPT2 performance in autism. However, they both compared groups of older ASD children to younger typical children. This suggests that at the very least the participants with autism may be displaying a delay in the development of VPT (similar performance to younger children as opposed to an age matched group) and that it may be inappropriate to label their performance as unimpaired. By comparing ASD participants to the appropriate control participants, it becomes possible to make stronger claims as to whether performance on a task is normal, impaired or simply delayed. These findings present a strong case for using carefully chosen control groups in studies looking for evidence of impairment in a population such as autism.

In this thesis, I will attempt to address some of these issues by examining VPT levels 1 and 2 in children with and without autism. I will examine which processes underlie these abilities and whether there is any evidence of them being impaired in autism.

1.4 Theory of Mind

Mentalising, or Theory of Mind (ToM), is the process we use to understand the thoughts, beliefs and desires of others (Frith & Frith, 2007). ToM provides us with an insight into the way others think and feel, which allows us to be more skilled at social interaction. We begin to develop ToM ability early in childhood, moving away from a purely egocentric view of the world to taking others thoughts into account (Leslie, 1987; Wimmer & Perner, 1983). Hence ToM is also referred to as cognitive perspective taking (Baron-Cohen, 1989). This is the point at which children begin to understand that other minds may hold thoughts and information different to their own. Whilst it is unclear whether body representation and spatial transformations are impaired in people with autism, deficits in ToM are widely accepted to be a key feature of the disorder (Abell, et al., 2003; Baron-Cohen, 1995; Baron-Cohen, et al., 1985; Fletcher, et al., 1995; Frith & Frith, 2007; Frith, 2001; Senju, 2012). It is possible that ToM and VPT2 are related as they both rely upon the simultaneous representation of different viewpoints. Here ToM in typical and autistic individuals is explored.

Wimmer and Perner (1983) developed one of the most well-known ToM tasks, designed to measure understanding of false belief. In this task children are presented with a story about two characters: Sally and Anne (Figure 1.6). In the story, one of the characters has an item. They leave the item and while they are away the other character moves the item to a new location. The child is then asked where the character will look for their item. In order to pass the task the child must be able to recognise that their knowledge about where the item is and the characters belief about where the item is, are different. They found that children between the ages of 4 and 6 were able to separate their knowledge about the whereabouts of the item from the characters knowledge, but children below the age of 4 were not, stating that the character would look in the new (unbeknown to them) location. This task has been referred to as an ‘explicit false belief task’ as children must be able to explicitly verbalise the difference between their belief and that of the character. It has been argued that this strong verbal component may in fact influence the age at which children are seen to pass ToM tasks (Astington & Jenkins, 1999). Explicit ToM also has memory components which may affect task performance in younger children, as they must remember where the character originally placed the item at the beginning of the story.

The age at which ToM develops has been the subject of debate in recent years. Originally, ToM was thought to develop at around 4-5 years of age (Wimmer & Perner, 1983) with children below 4 years typically failing tests of ToM. More recent ToM research has examined the possibility that ToM may begin to develop as early as infancy, but that younger children fail explicit ToM tasks due to language and memory demands (Kovacs, Teglas, & Endress, 2010). The use of eye tracking has been suggested as a more implicit way of measuring ToM in younger children. Senju, Southgate, Snape, Leonard, and Csibra (2011) developed a paradigm in which a false belief task story was presented visually using puppets and actors. Infants were presented with two puppet show versions of the false belief task, one in which the character wears a blindfold while their item is moved to another location, and another where the character sees the item be moved. Instead of asking the infant where the character would look for their missing item, the child’s anticipatory eye movements were tracked. If the child understood that the adult did not see the item move in the blindfold condition then they should anticipate that the adult will check the original location, whereas when the adult was not blindfolded they would anticipate the adult looking to the new location. They found that TD infants did in fact display anticipatory eye movements to the correct region in the false belief task, suggesting they had implicit understanding of what others could and couldn’t see. These findings have been replicated in younger infants (7 months) (Kovacs, et al., 2010), suggesting that aspects of ToM may be a very automatic and innate process in typically developing children (Scholl & Leslie, 2001). Thus, it has been suggested that there may be two pathways for mentalising: one which develops early in toddlers and is automatic and implicit (as shown in the implicit false belief task) and the other which develops much later, and relies on more complex cognitive skills, as seen in the explicit ToM tasks (Apperly & Butterfill, 2009). Apperly and Butterfill (2009) proposed a dual route theory which takes into account the different demands present in mentalising. They suggested that from infancy there exists an automatic but inflexible system for processing the beliefs of others. As a person develops, they gain knowledge about the concept of desire and belief that allows them to use top down conceptual experience to reason about other’s mental states in a much more flexible and efficient way. Thus, it appears that in TD people, ToM is a well-developed and flexible ability which allows for more efficient social interaction.

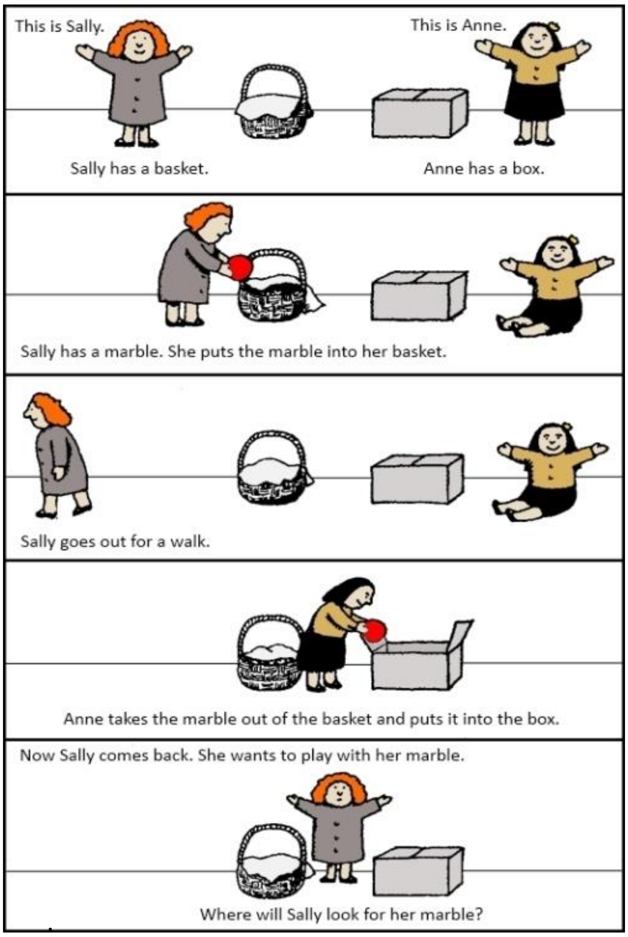

Figure 1.6 Visual step by step example of the Sally-Anne Theory of Mind task.

1.4.1 Theory of Mind in Autism

Theory of mind is well documented to be impaired in people with autism, with multiple studies showing that they have difficulty understanding the mental states of others (Abell, et al., 2003; Baron-Cohen, 1995; Baron-Cohen, et al., 1985; Fletcher, et al., 1995; Frith & Frith, 2007; Frith, 2001; Senju, 2012). In comparison to typical children the ability to pass explicit ToM tasks develops much later in children with autism, at around 9 years of age (Baron-Cohen, et al., 1985; Happe, 1995). By adulthood, higher functioning autistic participants are able to reason about other people's beliefs (Ozonoff, Pennington, & Rogers, 1991), though performance is still worse than that of TD individuals.

Research has also shown that children with ASD do not demonstrate the same anticipatory eye movements as typical children in implicit ToM tasks (Senju et al., 2010).The study was replicated in adults with ASD and findings were striking; even the adults with autism did not show the anticipatory eye movements found in TD infants (Senju, Southgate, White, & Frith, 2009). It is possible that people with ASD are able to develop some ToM skills using conceptual information about others, but do not develop the automatic system seen in TD children. Thus it appears that for people with autism, ToM is much more effortful and less reflexive than seen in TD individuals.

Some researchers have argued that ToM may not be driven by the same mechanisms in typical and ASD individuals (Tan & Harris, 1991). Tan and Harris suggested that people with autism may rely on different sources of information in order to complete ToM. Whilst we know that ToM contributes towards difficulty in social interaction in autism, so far it is unclear whether VPT could also explain some of this impairment. Whilst this thesis seeks to answer this question, it will also investigate the relationship between ToM and VPT in order to examine whether they may be related in people with autism.

1.5 Aims of this Thesis

So far four processes have been linked to the ability to see things from another person's point of view: spatial transformations, body representation, visual perspective taking and theory of mind. This thesis has two aims: The first is to investigate each of these processes in people with autism to assess whether they show any impairment. The second is to investigate how these processes may relate to each other and whether difficulty in performing them could contribute towards difficulty in social interaction. Each of the five experimental chapters will focus on a different process to build a picture of how people with autism use their body and the space around them to inform social interaction. Chapter 2 will investigate whether children with autism show impaired body representations compared to TD children. Problems with body representation could impact on the ability to perform VPT through difficulty in representing how other people look and the orientation of their body. Chapter 3 will examine both mental rotation and egocentric spatial transformations in order to investigate whether problems in general spatial transformations or impairments in transforming the self could account for difficulties in VPT. Chapter 4 and 5 will investigate the how the processes examined in Chapters 2 and 3 relate to VPT2 in TD and ASD children. They will also further explore the relationship between ToM and VPT2 in people with autism, asking whether the two may be related. Finally chapter 6 will examine VPT1 in children with

ASD compared to TD children in order to establish whether this ability may be impaired.

2 Body Representation in Children with Autism

In the introduction to this thesis several processes were discussed in relation to the contribution they may have toward visual perspective taking. This chapter will focus on body representation in children with and without autism. Specifically, it will examine both the perception of bodies and knowledge about body postures.

In order to put yourself in someone else's place it is likely that you will need to have some understanding of the other person's body. When we see a person we encode a visual description of their hands, body and relevant objects. This description is linked to brain regions such as the fusiform body area (FBA) (Peelen & Downing, 2007). This visual description might then be linked to the observer's own motor representations in the mirror neuron system (MNS) (Rizzolatti & Sinigaglia, 2010). These processes provide information about the way other people look and move in space which in turn can help us to understand how the world may appear from their point of view. Body representations are essential for performing egocentric transformations. In order to transform the self, one must first create a motor representation of the target posture (Grush, 2004). This allows for a mapping between bodies and the transformation from one perspective to another.

Research as to whether body representation is intact in autism has so far been inconsistent. Though there is extensive evidence that theory of mind is difficult for people with autism (Baron-Cohen, et al., 1985; Happe, 1995; Senju, et al., 2009) due to its abstract nature (Leslie, 1987), it has been debated whether people with autism are able to perceive and represent more concrete social information, such as bodies. Bodies are concrete stimuli as we can see them and view when they change. Mental states however cannot be seen and require more abstract representations (Leslie, 1987). Previous studies of autism have shown contradictory findings with regards to whether people with autism are impaired at perceptual body processing (Jones, et al., 2011; Pellicano, Gibson, Maybery, Durkin, & Badcock, 2005) and posture knowledge (Hamilton, et al., 2007; Reed, et al., 2007). The aim of this study is to examine how people with autism perceive and understand body postures in order to provide evidence as to whether these abilities may be impaired.

When typical individuals perceive a body, their representations of the body are organised within a spatial hierarchy (Gliga & Dehaene-Lambertz, 2005). In this hierarchy whole body templates, including the relative position of limbs, are coded in order to perform efficient posture recognition (Peelen & Downing, 2007). This is termed configural processing (Johnson, et al., 1979). An indication of the strength of configural processing is the body inversion effect. Reed, et al. (2007) studied configural body processing in adults with autism using a body inversion paradigm. Here participants had to decide whether two pictures of an upright or inverted (upside down) body, face or house were the same or different. Typical participants showed an inversion effect (slower reaction times to inverted bodies compared to upright ones) whereas adults with ASD did not. This provides initial evidence for atypical configural processing of bodies in adults with ASD, suggesting that they do not use the same configural processing strategy as TD people.

A limitation of the method used by Reed et al. is that both target and comparison pictures were shown from the same viewpoint (both upright and forward facing), which meant that participants could match using surface features as opposed to a configural strategy. Surface features are arbitrary features of a posture such as the position of a limb, which when compared in two matched viewpoint pictures will map directly from one onto the other. Previous research has shown that participants with autism tend to favour a strategy based upon surface feature matching when presented with rotated stimuli (Falter, et al., 2008), a difference related to weak central coherence . This makes it difficult to conclude whether differences between groups in Reed's study are a result of impairment due to abnormal body processing in autism, or intact body processing mediated by reliance on a different processing strategy.

Posture matching has previously been used to study body perception in children with autism. Ham, et al. (2008) used a posture matching task (Goldenberg, 1999) alongside measures of gesture imitation in which ASD children and age and IQ matched TD children had to imitate hand/finger positions. Ham's study used meaningless gestures/postures only to control for posture knowledge (which would tap into MNS processing) influencing recognition. They found that participants with ASD showed a significant deficit in hand/finger matching as well as posture imitation compared to the TD controls. Ham et al. minimised the possibility of matching on the basis of surface features by presenting posture matching stimuli from different viewpoints, which makes it more difficult to map directly from one stimulus onto the other. These results suggest that when a feature matching strategy is more difficult for people with autism to use, they may struggle to match postures. The method used by Ham et al. is a useful way to examine body perception in autism as it taps into the ability to perceive the body from different viewpoints whilst limiting the use of feature-based strategies.

Body posture knowledge can be examined by testing the semantic knowledge of the shape of the hand or body in a variety of familiar actions. Here motor representations of a posture are compared to those stored in the viewer’s own motor repertoire in the human mirror neuron system (Buxbaum, Kyle, & Menon, 2005). Research carried out by Smith and Bryson (1998) and (2007) found that children with ASD were able to both recognise and match postures in a posture matching task depicting both socially communicative meaningful and non-symbolic postures. This result has since been replicated by Hamilton, et al. (2007) who used a task developed for adults with apraxia by Heilman & colleagues (Mozaz, Roth, Anderson, Crucian, & Heilman, 2002). In this task, participants are presented with a line-drawing of a person performing an everyday action with the hands (and object) missing from the picture. On a second card, participants see three photos of hands (with no object) with one photo of a correct posture and two foils; the participant must choose which photo would 'fill the gap'. There is more than one version of this test in use, but most have one set of pictures showing intransitive actions (often social actions such as waving goodbye) and another set showing transitive actions (tool-use actions such as ironing). Hamilton and colleagues found no differences in performance between a group of children with ASD and a group of verbal mental age (VMA) matched typical children on both types of actions. However, Dowell, Mahone, and Mostofsky (2009) examined older and more able children with ASD compared to age matched typical children (8-13 years) using a similar paradigm and found a difference between groups, with the ASD children performing worse than the TD. All of the above studies use different age groups and different matching criteria for their typical participants, with some matching on age and others on verbal ability. Recently it has been suggested that these methods may not be optimal for comparing clinical and non-clinical groups (Jarrold & Brock, 2004) as IQ profiles are not the same in people with developmental disorders and those who are typically developing. The results from these studies have made it difficult to conclude whether people with ASD have impaired posture knowledge.

The aim of the current study was to investigate viewpoint independent posture perception and representation in children with ASD children compared to TD children and children with moderate learning difficulties (MLD). Two different task sets (body inversion and posture matching) can engage the detailed perceptual and motor processing systems that may provide important inputs to social reasoning systems. Cross, Hamilton, Kraemer, Kelley, and Grafton (2009) found that processing whole body images from multiple viewpoints engages both perceptual systems and MNS regions, effectively tapping into both body perception and posture knowledge. Thus this study uses viewpoint independent images of stimuli to try and limit reliance on surface features and encourage recruitment of a wider processing network.

Engagement of mirror systems is modulated by action familiarity (Calvo-Merino, Ehrenberg, Leung, & Haggard, 2010; Cross, Hamilton, & Grafton, 2006) and so meaningful postures are included as well as meaningless (Ham, et al., 2008). A large group of TD developing children were included as controls as this approach allows for comparison of the developmental trajectories for different groups (Jarrold & Brock, 2004; Thomas et al., 2009). A group of children with MLD were used as a second comparison group so that we could test if any differences in task performance to the typical group were related to general learning difficulties (which would result in worse performance for both the MLD and ASD groups) or specific to autism (worse performance in the ASD group only). The parents of the ASD and MLD children also completed the social communication questionnaire (SCQ) (Berument, Rutter, Lord, Pickles, & Bailey, 1999) to provide a current assessment of their child's social skills, allowing us to link social skills to task performance.

In the current experiment, participants are presented with two images of a body, hand or object shown from two different points of view together with a foil picture (Figure 2). The participant must select the target picture rather than the foil. Correct responses on this task cannot be given by matching based on the outline shape of the body/object, thus avoiding one limitation of Reed's stimuli. Hands were included as several studies examining body representation in autism have also used hands as stimuli (Ham, et al., 2008; Hamilton, et al., 2007). Objects were used as a control stimulus as previous studies have shown people with autism to have no problems at the perception and representation of objects (Reed, et al., 2007). A 2x3x3 factorial design was used, comparing performance on both meaningful and meaningless bodies, hands and objects shown from different viewpoints. If children with ASD have a difficulty in the perceptual processing of hand and body postures they should show worse performance on both the meaningful and meaningless hands and bodies compared to the control groups. If children with ASD have with difficulty posture knowledge and comparing postures to their own motor representations, they should only show worse performance on the meaningful hands and bodies. In both cases any difficulties which are specific to ASD should be related to a child's SCQ score, a measure of their social ability.

2.1 Method

2.1.1 Participants

A total of 105 children from three groups participated in the study. Twenty three children with a diagnosis of autism or autism spectrum disorder were recruited from schools in the Nottingham and Wales area. Their mean chronological age was 9.43 years and 21 were male (see Table 2.1). The British Picture Vocabulary Scale (BPVS) (Dunn, Dunn, Whetton, & Burley, 1997) was used to establish each child's verbal mental age. All children had a previous independent diagnosis from a clinician, however, the Social Communication Questionnaire (Berument, et al., 1999) was also completed by a caregiver to evaluate the child's social understanding and communication skills. Data from sixteen children with MLD were also collected. These children had a mean chronological age of 8.88 years and 13 were male. These children were recruited in the same way as the ASD children, and they also completed the BPVS and SCQ (see Table 2.1). The ASD and MLD children differed significantly on raw BPVS score ($t(36) = -2.719$, $p = 0.010$), BPVS standardised score ($t(36) = 3.345$, $p = 0.002$) and SCQ score ($t(36) = 5.698$, $p < 0.001$) but were similar in terms of age ($t(36) = 1.096$, $p = 0.280$).

In addition sixty-six typically developing children (mean chronological age: 5.51) were tested. The typically developing children were recruited during Nottingham University's Summer Scientist Week, an event designed to recruit children to take part in various studies in the form of short "games". All TD children completed the BPVS; however instead of the SCQ, a caregiver completed the Social Aptitude Scale (SAS) (Liddle, Batty, & Goodman, 2009), a questionnaire designed to measure social skills in non-clinical populations (see Table 2.1). A parent or caregiver also confirmed that the child did not have a diagnosis of autism or any other disorder using a background questionnaire. The TD group differed significantly from the ASD group ($t(86) = 12.583$, $p<0.001$) and the MLD group ($t(80) = 9.860$, $p<0.001$) in regards to age. They also differed significantly from the ASD group in regards to BPVS raw score ($t(86) = 4.060$, $p<0.001$) and standardised ($t(86) = 10.291$, $p<0.001$). The TD group had a similar BPVS raw score ($t(80) = 0.043$, $p=0.966$) to the MLD group however they differed significantly on standardised score ($t(80) = 5.114$, $p<0.001$).

Table 2.1: Descriptive Statistics for each group, reported as mean ±S.D (range)

	N	Age	SCQ	BPVS Standardised	BPVS Raw	VMA
ASD	23	9.43 ± 1.47 (5.79-11.73)	19.3 ± 6.38 (4-30)	109.78±11.21 (79-137)	46.09 ±22.65 (10-93)	4.42±2.10 (2.05-9.04)
MLD	16	8.88 ± 1.54 (6.32-11.25)	7.71 ± 5.25 (1-16)	63.27±18.32 (39-90)	66 ± 18.51 (40-102)	6.11±1.97 (3.09-10.08)
TD	66	5.53 ± 1.17 (4.04-7.94)	-	83.13±17.70 (44-107)	66.21 ± 17.32 (24-108)	6.12±1.81 (2.11-11.07)

The study was approved by the School of Psychology ethics board. Both parental and child consent was gained for all participants, as well as the schools that took part in the study. ASD and MLD children were tested individually in a quiet room in his or her own school, whereas the typically developing children were tested in a quiet, partitioned cubicle in a room set up for the Summer Scientist data collection.

2.1.2 Design

The study had a 2x3x3 repeated measures design, with two levels of meaning (meaningful / meaningless) and three levels of stimulus form (body / hand / object) (resulting in 6 stimulus categories in total) and three levels of group (TD/ASD/MLD). Children's performance was measured in terms of accuracy (percentage correct) but it was not possible to collect reaction time data from this sample. Stimuli were presented in six blocks of the same stimulus category (i.e. meaningful bodies) because mixing meaningful and meaningless stimuli reduces the impact of meaning (Tessari & Rumiati, 2004). Stimulus order was pseudo-randomised within a block and block order was counterbalanced across participants.

2.1.3 Stimuli and Piloting

The stimuli for this study included photographs from three categories: hands, bodies and objects, with meaningful and meaningless items in each category. Stimuli were created by taking photos of the relevant item (hand / whole person / object) on a stage which was set up so that two cameras could simultaneously photograph the stimulus item from different orientations (45º left of centre and 45º right of centre) (see Fig 2.1). The picture from one camera was used as an exemplar picture while the picture from the other camera was used as a target picture. A picture of a different item from the same category was taken in the same session and used as the foil picture. Examples of each item from each category are shown in Figure 2.1B. Stimuli defined as ‘meaningful’ depicted familiar objects or postures: for bodies and hands these would be familiar or communicative postures (such as a ‘thumbs up’ for hands) whereas for objects familiar everyday objects were chosen, such as toys, tools and foods which could be used in a meaningful way (i.e a ball which can be thrown, or a box which could be opened). For 'meaningless' stimuli, unfamiliar postures were used for bodies and hands (i.e. a random limb configuration for bodies) and a random assembly of toy bricks were used as meaningless objects.

A pilot study was conducted in order to equate task difficulty between stimulus categories. From the initial photography sessions, fifteen stimulus trios (exemplar, match and foil) were selected for each of the six stimulus categories (meaningful and meaningless hands, bodies and objects). This large stimulus set was used in a pilot experiment in which adult participants performed the viewpoint-independent picture matching as a reaction time task. On each trial, the participant saw an exemplar picture at the top of the screen, and a target and foil picture at the bottom of the screen (randomised as to which appeared on the left or the right). The participant pressed 'Z' on the keyboard if the exemplar matched the picture on the left, and 'M' if it matched the picture on the right. Both reaction time and error rates were recorded and analysed using Matlab 6.5. Twelve typical adult participants (university students) completed the pilot. Results were analysed to calculate the mean reaction time and mean error rate for each stimulus trio. These data were plotted with each stimulus trio as a single data point. Six trios were selected from each stimulus category, and were chosen on the basis that they had the most similar response times and error rates. . Stimulus trios which were either very easy or very difficult to match were excluded, so that the final sets of trios were equated for task difficulty across category.

There were 38 final trios in total, 2 of which were used as stimuli for practice trials, one meaningful (a body) and one meaningless (an object) and 36 trios were the stimuli used in the main experiment (6 trios and 6 categories).

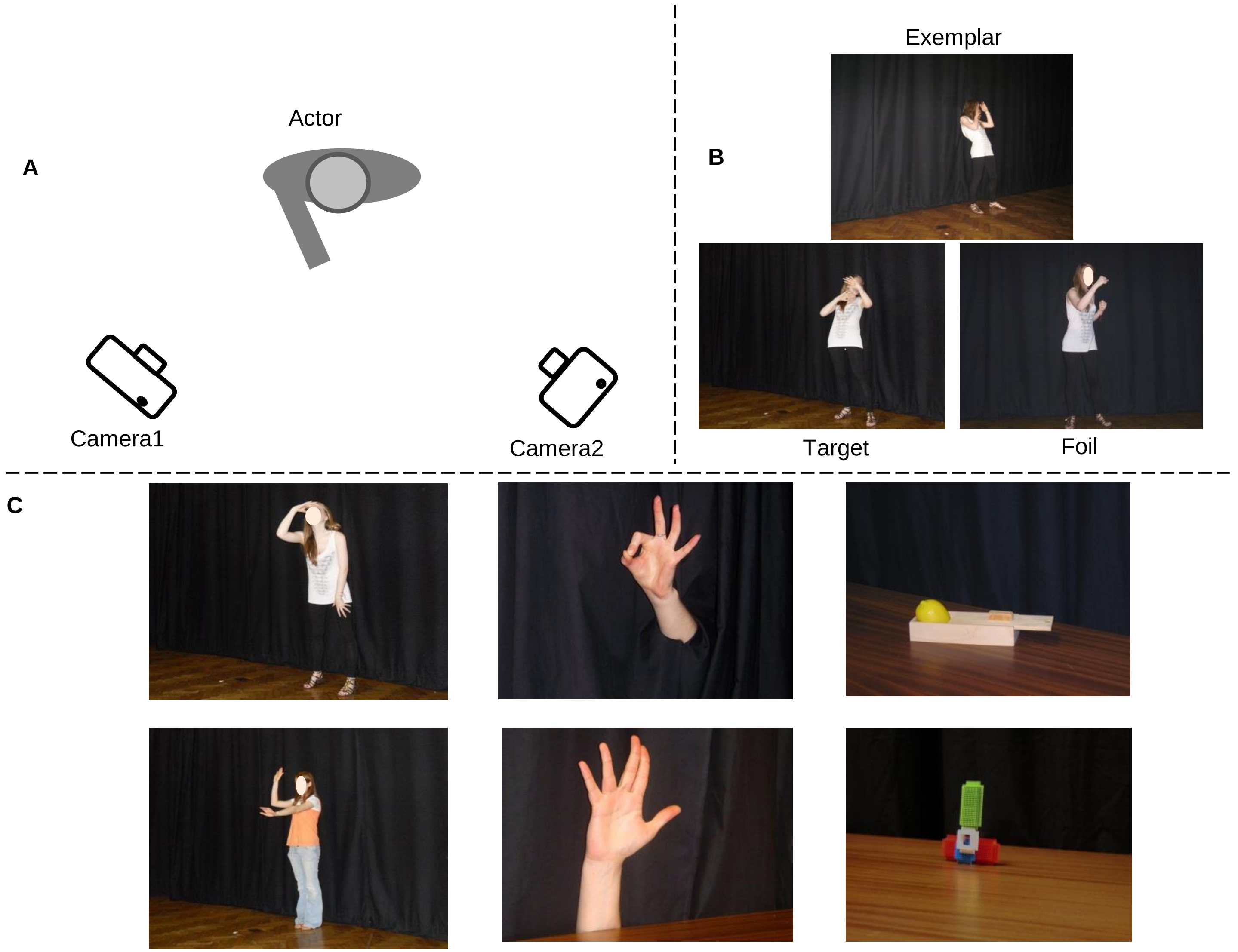

Figure 2.1 Configuration of cameras for the photography sessions. **B**. A sample stimulus trio consisting of an exemplar, a target and a foil image. **C.** Sample exemplar images from each of the six stimulus categories (meaningful above, meaningless below).

2.1.4 Procedure

Children sat at a table with the experimenter. The child was shown a laminated card with two pictures (the target and foil) and told “here are two pictures”. Then the experimenter showed the child a second laminated card with a single picture (the exemplar) and said “Here is another picture, which one of these (point to double picture card) matches your picture?” The child could respond verbally (by saying ‘the picture on the left/right’), by pointing or putting the single card with the appropriate match. The first two trials were given as practice trials, and any errors the child made were corrected with an explanation (for example, ‘can you see how the lady has her arm like this in this picture and her arm the same in that picture). After the child understood the task, the experimenter presented the 36 experimental trials. During these trials, encouragement was given throughout regardless of the child’s answer and breaks were given as needed. Children also completed the BPVS in a separate session.

2.2 Results

On the posture task a score of 1 was given for each correct answer. The total number correct out of six was then transformed into a percentage of correct responses for each stimulus category.

An ANCOVA compared performance across all three groups, with factors of form (body, hand and object) and meaning (meaningful and meaningless) and covariates of age and BPVS standardised score.

BPVS standardised was used as age and BPVS raw score are highly correlated. There was no significant effect of diagnostic group upon accuracy (F (2, 99) =2.03 p=0.137). There was a significant effect of age (F (1, 99) =4.34, p=0.040) and a significant effect of BPVS standardised (F (1, 99) =9.82, p=0.002) with older and higher BPVS children having higher levels of accuracy. Effect size (measured using partial eta squared) showed that BPVS (0.090) had a larger effect on performance than age (0.042). There was a significant effect of form (F (2, 198) =9.18, p<0.001) with lower accuracy on the body and a significant effect of meaning (F (1, 99) =15.05 p<0.001), with higher accuracy for the meaningless stimuli as opposed to meaningful. There was a significant interaction between meaning and form (F (2, 198) =8.99, p<0.001), with a significant decrease in accuracy for the meaningful body stimuli compared to all other stimuli (Figure 2.2). There was also a significant interaction between form and BPVS score (F (2, 198) =3.23, p=0.042) and form and age (F (2, 198) = 2/369, p=0.096). There were no two-way interactions between form and group (p=0.63), meaning and age (p=0.29), meaning and BPVS score (p=0.93) and meaning and group (p=0.33). There were also no three way interactions between form, meaning and age (p=0.37), form, meaning and BPVS score (p=0.31) or form, meaning and group (p=0.41).

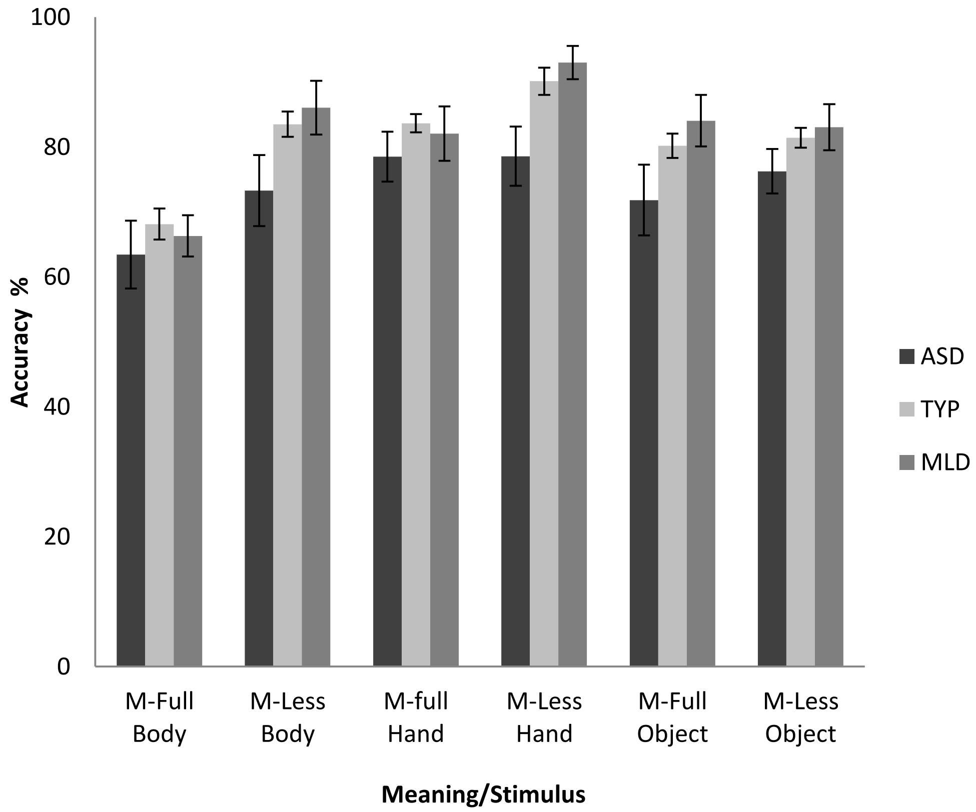

Figure 2.2 The effects of group, stimulus and meaning on accuracy (% correct) with errors bars to show S.E. The darkest bars represent the ASD group.

To examine the effects of SCQ on task performance, data from the ASD and MLD groups were combined and entered into an ANCOVA, with within subjects variables of form and meaning, and covariates of SCQ, BPVS standardised and age. Diagnosis was not included here because it correlates highly with SCQ. There was a significant effect of form (F (2, 68) =3.81, p=0.03), with participants least accurate for bodies compared to hands and objects. There was a marginal effect of meaning (F (1, 34) =3.648, p=0.065), with participants being more accurate on the meaningless stimuli and a marginal form by meaning interaction ($F(2, 68) = 2.91$, $p=0.061$). There was also a significant effect of BPVS standardised ($F(1, 34) = 24.74$, $p<0.001$), with children scoring higher on the BPVS performing more accurately and an effect of age ($F(1, 34) = 8.85$, $p=0.005$) with older children performing better. There was no significant effect of SCQ. There were no significant two way interactions between form and age ($p=0.133$), form and SCQ ($p=0.897$), form and BPVS score ($p=0.713$), meaning and SCQ ($p=0.726$) or meaning and BPVS score ($p=0.742$). There were also no three way interactions between form, meaning and age ($p=0.744$), form, meaning and SCQ ($p=0.381$) or form, meaning and BPVS score ($p=0.885$).

2.3 Discussion

This study examined body and object representation in children with and without ASD. There were no significant differences in accuracy between the ASD group and comparison groups. The results from this study suggest that children with ASD do not have a problem with constructing viewpoint independent representations of bodies, hands and objects. The lack of a group difference in body representation contrasts with previous research by Reed et al. (2007), who found that ASD participants displayed atypical representation of bodies in a posture matching task. There are several differences between these studies, including the population studied (children vs. adults) and the task used. Reed's task measured a subtle body inversion effect seen in reaction time data, whereas the current study measured accuracy in viewpoint independent posture matching. It is possible that a reaction time version of the current task would reveal more subtle group differences but it was not feasible to measure RT with the low-functioning children tested in this study. The results in the current study suggest ASD individuals do not have a gross deficit at recognising the features of a body, and mapping these features across different orientations.

The lack of a group difference is also consistent with the lack of an effect of SCQ on performance. If failure of basic hand and body representation makes a critical contribution to social ability in children with autism, we would expect SCQ to predict performance in the current task. No relationship was found between SCQ and performance on the experimental tasks. While caution must be taken about making strong claims based on a lack of an effect, it seems that hand and body representation may not be a primary driving factor in poor social interaction skills.

Effects of stimulus category and meaning

This data revealed a main effect of stimulus meaning, with lower accuracy on meaningful stimuli compared to meaningless, and a main effect of stimulus form with lower accuracy on body stimuli compared to hands and objects. There was also a stimulus form by meaning interaction, with worst performance on meaningful body postures. These effects were consistent across all participant groups. These findings contrast with studies shown an advantage for processing meaningful stimuli (Bosbach, Knoblich, Reed, Cole, & Prinz, 2006) in which it has been shown that prior knowledge of postures aids recognition in posture matching paradigms.

These effects of category and meaning may best be understood in terms of differences in performance between children (age 5-12) and adults. The stimulus trios were piloted on adult participants and selected to equate difficulty across category in this group. If adults show an advantage for meaningful stimuli (Bosbach, et al., 2006), this selection procedure would give us stimulus trios which are intrinsically harder to match in the meaningful group because adults can use their knowledge of the stimulus meaning to overcome complex stimuli. This may result in less well matched difficulty across categories with more complex stimuli in the meaningful category than the meaningless.

These data also show an interaction between meaning and category, with worse performance on the meaningful body stimuli. This suggests that the development of semantic knowledge about meaningful body posture is delayed relative to the development of knowledge of meaningful hand postures and meaningful objects. As there were no effects of group, it seems that this pattern of development is consistent across children with and without autism. Further studies would be needed to follow the development of different types of posture knowledge over childhood.

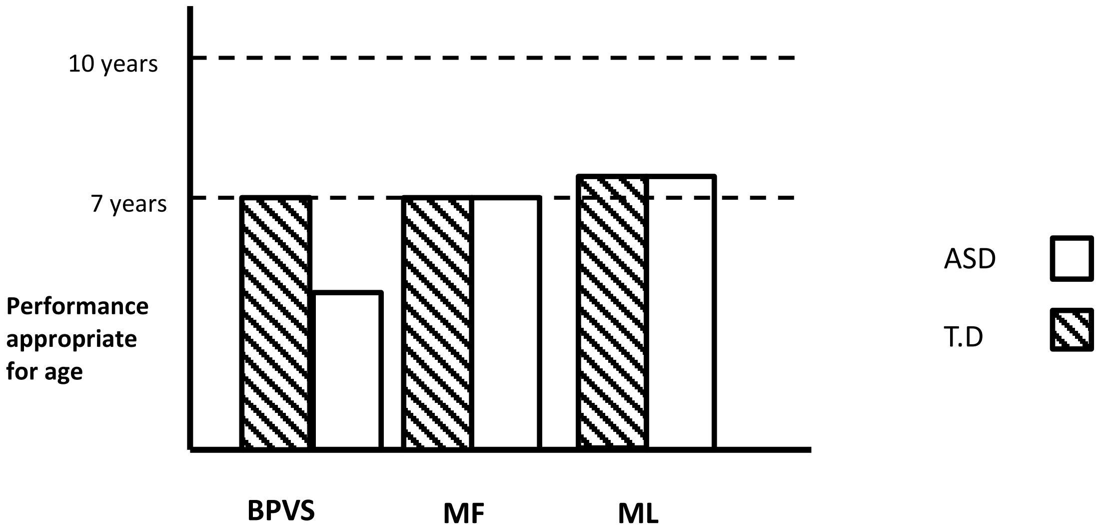

Figure 2.3 This figure sketches performance for the TD and ASD groups in relation to what would be expected in performance appropriate to age. The TD group are showing age appropriate performance on the BPVS, and meaningful and meaningless bodies. The ASD group are showing below age performance on the BPVS, and performance expected for 7 year olds on the bodies task.

Verbal ability and body representation

Children's performance on the body representation task was strongly predicted by BPVS standardised score and age across groups. Results showed that out of these two variables, verbal ability was a stronger predictor of performance than age. The ASD group were older than the TD group; however they had a lower verbal ability (see Figure 2.3). Figure 2.3 depicts a sketch of performance for the body conditions and BPVS for the TD and ASD groups. The ASD group were performing lower than would be expected for their CA, but higher than would be expected for their VMA. Though it is difficult to conclude that the ASD group is truly unimpaired on the body representation task (they are performing the same as younger, but more abled TD children), findings suggest that children with ASD may not have any specific difficulties in representing the human body or hand beyond their general learning difficulties.

These data are consistent with previous findings from Jones et al (2011) who conducted a biological motion study on eighty nine adolescents with ASD to examine the ability to identify bodies in point light displays. They found that the ASD group did not perform significantly different to the typical group, but that IQ was a significant predictor of task performance. These findings suggest that even in tasks with minimal verbal demands, verbal ability can be a strong predictor of ability. In the future, it would be interesting to examine children with autism alongside verbal ability matched TD children to investigate whether a lack of difference between the groups is maintained. Chapter 5 will examine VMA matched TD and ASD children on body representation only (not hands or objects) in order to further investigate body representation in ASD.

Limitations

One limitation of the current study is that reaction time was not collected from the children, as was collected with adults in the pilot study. This is because the computerised version of the task which records reaction time was not suitable for use with the low-ability children tested in this study, and would not yield reliable results if it had been attempted. The accuracy data collected provides the most realistic assessment of these children's abilities. However, it is possible that collecting response time data would allow for more subtle differences between groups to be revealed. In Chapter 3 adults with ASD will complete a task which examines spatial transformations of both bodies and objects. Any specific difficulty relating to bodies should be seen in this data.

A further limitation of the current study is that the range of BPVS scores in the ASD group extended below the range of the other groups, and overall the ASD group had a lower mean BPVS score. Though BPVS significantly predicted performance, there were no effects of group. Thus, the children with ASD were performing at the level expected for their general cognitive abilities. However, generally in studies using a developmental trajectory approach the control group should span the range of youngest verbal mental age (VMA) participant in the ASD group (in this case 2.11 years old) and the oldest chronological age (CA) participant in the ASD group (in this case 11.73) years old. The children in the current TD sample only span the ages of 4-8 years old and therefore do not fully meet the assumptions of the developmental trajectory approach. The data from the TD children was collected during an event at which the minimum age to attend was 4 years of age. Though the highest VMA in the TD group was similar to that of the highest CA in the ASD group (11.07), there was no match for the lowest VMA in the ASD group. In future, efforts should be made to collect a TD sample which spans the full range of the experimental group. This will allow for a clearer plotting of the developmental trajectories in each.

2.4 Broader Implications

These findings provide us with some insight into possible factors which contribute towards visuospatial perspective taking skills in typical and ASD children. It is difficult to conclude from the findings of the current study whether visual and motor representations of bodies are truly intact in people on the autism spectrum. Further research is required to explicitly examine the relationship between VPT and body representation, however the current study suggests that difficulties in VPT in autism may not be related to poor body representation skills.

3 Spatial Transformations of Bodies and Objects in Adults with ASD

Spatial transformations are the process we use to mentally realign one spatial position with another. It is likely that certain types of spatial transformation are important for social interaction because they allow us to put ourselves in someone else's place (Michelon & Zacks, 2006). Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterised by deficits in social communication and restricted interests (Wing & Gould, 1979). Whilst it is widely accepted that people with autism are impaired at representing the mental perspectives of other people (termed theory of mind (ToM)) (Baron-Cohen, et al., 1985; Frith & Frith, 2007; Frith, 2012; Senju, 2012), research into whether people with autism have trouble representing the visual perspectives of other people has shown somewhat more mixed findings (Hamilton, et al., 2009; Tan & Harris, 1991; Yirmiya, et al., 1994). Recently Hamilton, et al. (2009) showed that children with autism have difficulty with predicting the visual perspectives of other people compared to typically developing (TD) children, but are equally good at performing mental rotation. In order to see things from someone else's perspective, it is first necessary to put ourselves in their place by performing a spatial transformation. This chapter will investigate spatial transformations in adults with autism and consider how they might relate to impairments in perspective taking ability.

In attempting to investigate how spatial transformations may impact on visual perspective taking (VPT) in autism it is necessary to think about the different types of spatial transformation outlined in the literature. This chapter is concerned with the use of egocentric transformations and mental rotation. Egocentric (or ‘self-based’) transformations are the process we use to put ourselves in a different place. They use the body of the viewer as a reference frame in which the body is transformed as a whole into alignment with a new position in space (Zacks, et al., 1999). Egocentric transformations have also been referred to as ‘perspective transformations’ as they involve moving to a different perspective from the one the viewer currently occupies (Steggemann, et al., 2011). They are argued to be the underlying process used to complete VPT (Yu & Zacks, 2010), hence why they are of importance in the current study.

Mental rotation (or ‘object based’ transformation) is the process by which we can manipulate the orientation of objects in our minds (Shepard & Metzler, 1971; Wraga, et al., 2003). We use mental rotation to compare two objects from different viewpoints (Figure 3.1B). Mental rotation involves mentally transforming an external target/object until it corresponds with another stimulus. Though it has been argued that mental rotation could be used to take another person’s perspective (by rotating a scene as opposed to the self), it is a much less efficient way of doing so compared to an egocentric transformation (Zacks & Tversky, 2005).

Hamilton, et al. (2009) examined VPT and mental rotation in children with autism compared to a group of verbal mental age (VMA) matched TD children. In the VPT task children were presented with a toy on a turntable and asked to identify their own point of view on an answer sheet. The toy was then covered with an opaque pot and a doll placed at another spot on the table. The child was asked to identify the view of the toy that the doll would see when the pot was lifted. For the mental rotation task children were shown a toy on a turntable and asked to identify which picture on the answer sheet matched their current point of view. The toy was then covered with the opaque pot and rotated to a different orientation. The child was then asked to identify which view of the toy they would see when the pot was lifted. Results showed that the children with ASD were significantly less accurate on the VPT task compared to the typical children, but more accurate on the mental rotation task. If egocentric transformations are the process we use to complete VPT, Hamilton's paper suggests that egocentric transformations may be impaired in people with autism whilst the ability to perform mental rotation is intact. The current study aims to examine both mental rotation and egocentric transformations in adults with autism.

Egocentric Transformations

The link between egocentric transformations and perspective taking has been highlighted in a selection of behavioural studies. Typically, egocentric transformations are measures using laterality judgements. Parsons (1987) presented participants with images of bodies with an extended limb (i.e. an outstretched arm). These images were rotated in the depth plane (three dimensional rotations around a vertical axis) at various angular disparities. Participants were required to make a laterality judgement about the extended limb (i.e. '*is the extended arm a left or a right arm'*). In this study it was shown that the larger the angular disparity between the body of the participant and the target body, the longer the participant took to respond. It was argued that this relationship between response time and angular disparity was indicative of participants performing an imagined whole body transformation in which they mentally aligned themselves with the target. These findings have been replicated numerous times since in a variety of studies on egocentric transformations (Schwabe, et al., 2009; Wraga, et al., 2005; Zacks, et al., 1999). Recently, the literature on VPT has begun to make links between these underlying egocentric transformations and VPT itself. Zacks and Tversky (2005) had participants complete a task in which they had to make laterality judgements about the placement of an item in relation to another person's hands ('*the iron is next to her left hand')*. Participants reported that they made the decision by transforming their body to match that of the target person and then making the laterality decision. This provided evidence that egocentric transformations are the underlying step we use to take another person's perspective. Further evidence for the use of egocentric transformations in perspective taking comes from Kessler and Thomson (2009). In their study participants were presented with a scene in which an avatar was sitting at a table. An object was placed either side of the avatar (a flower and a gun) and participants had to make a laterality judgement about the placement of one of the items in relation to the avatar ('*is the flower on his left or right side*'). Results showed that response times increased as the angular disparity between the avatar and the participant increased. These findings provided strong evidence that the participants were performing an egocentric transformation into the viewpoint of the avatar in order to make a decision.

The laterality judgements used in egocentric transformations have previously been examined in people with autism. David, et al. (2010) examined perspective taking in high functioning adults with ASD compared to age and IQ matched TD adults. Participants were presented with images of an avatar which had an object placed at each of its sides. One of the items was elevated and participants were instructed to identify which object was elevated using a laterality judgement (the item on my right is higher). On half of the trials the participant was instructed to respond which object was elevated from their own current point of view, and on the other half they were instructed to say which object would be elevated from the perspective of the avatar. Results showed no significant differences in regards to response time *or* accuracy between the ASD and TD groups. This suggests that people with autism are able to make decisions about how things might appear to other people in regards to where the object is placed in relation to that person's body. However, in this study the angular disparity between the avatar and the participant remained constant. This makes it difficult to make any conclusions about whether people with autism are able to perform egocentric transformations in order to take another person's perspective at non-canonical (non-forward facing) rotations.

Recent research has attempted to investigate egocentric transformations and laterality judgements in people with high levels of autistic traits. It was shown that these people have difficulty with the use of egocentric transformations. Kessler and Wang (2012) examined participants using the task described in Kessler and Thomson (2009). A measure of autistic traits in these participants was taken using the AQ (Autism Quotient, (Baron-Cohen, Wheelwright, Skinner, et al., 2001)). The authors found that participants with higher levels of autistic traits displayed difficulty with performing egocentric transformations. These findings are not isolated. Brunye, et al. (2012) used a similar method to Kessler, presenting participants with an avatar seated at a table. A light appeared to either side of the avatar and the participant had to make a laterality judgement as to whether the light was on the participant's right or left side. Brunye and colleagues also used the AQ to measure autistic traits in the participants and found that those who had higher levels of autistic traits were slower to perform egocentric transformations then low AQ scorers.

The results of these studies suggest that people with autism or high levels of autistic traits may find egocentric transformations particularly difficult. Egocentric transformations are a highly embodied process, meaning they use a participants own body as a reference frame for putting themselves in another place (Kessler & Thomson, 2009; Schwabe, et al., 2009; Zacks, et al., 1999). It has been suggested that people with autism may be impaired at using their body as a reference frame. Eigsti (2013) argued that people with autism may have a general embodiment deficit based on previous findings of abnormal imitation and motor skills. It was suggested that they were unable to use their body as a reference frame to think about planning or performing physical actions. If this is the case then it stands to reason that they would also have problems with performing imagined body movements or transformations. Dowell, et al. (2009) found that children with autism showed motor abnormalities (such as poor motor planning) which they attributed to difficulties in proprioception. Research has shown that proprioception may be important for egocentric transformations as it lets us know where our body is in space and what it would feel like in different positions (Kessler & Rutherford, 2010). Similarly Carmody, et al. (2001) showed that children with autism found performing spatial tasks difficult due to a misalignment in body posture representation which led to an impaired body centred frame of reference. When children were asked to perform tasks such as catching a ball, impairments in proprioception meant that they were unable to accurately estimate the current position of their body and how much they needed to move. Together these findings suggest that people with autism may have impaired embodiment abilities which would make egocentric transformations difficult compared to TD people.

Based on previous findings in both TD participants with high levels of autistic traits and individuals with ASD themselves (Brunye, et al., 2012; Carmody, et al., 2001; Dowell, et al., 2009; Kessler & Wang, 2012; Shelton, et al., 2012), it is expected that in the current study, adults with autism will show impaired performance on the egocentric task compared to TD participants.

Mental Rotation

In Hamilton et al (2009)'s study, mental rotation was used as a general measure of spatial ability in the typical and ASD children. It was shown that the children with autism were impaired at performing VPT but had intact mental rotation. Her results suggest that people with autism are not impaired at performing all spatial transformations, but just those which use the self as a reference frame. Mental rotation is typically examined using the classic same/different judgement task (Shepard & Metzler, 1971) seen in Fig 1B. In mental rotation participants are presented with two objects, one reference object and another object rotated through various orientations (the target). Like egocentric transformations, mental rotation displays a linear relationship between angular disparity and response time. The larger the angular disparity between the two objects the longer participants take to respond (Shepard & Metzler, 1971). This is argued to be an indication of mental imagery in participants: time to perform mental rotation is comparable to the time it would take to physically transform an objects position. Typically developing people perform mental rotation configurally. This means they rotate the target stimulus in its current configuration as a whole into alignment with the reference stimulus and then compare the reference and target to decide whether they are the same. This has been shown to be the case across a variety of objects such as letters and geometric shapes (Kosslyn, et al., 1998).

Several studies have shown that people with ASD appear to have intact mental rotation ability (Falter, et al., 2008; Hamilton, et al., 2009; Soulieres, et al., 2011). Prior to Hamilton, Falter et al (2008) conducted a replication of Shepard and Metzler's 1971 mental rotation task on typical and ASD children. They found that children with autism were quicker to make the initial decision about whether two stimuli were the same or different than age matched typical children. However, Falter found subtle differences between groups that suggested ASD participants may have been matching across surface features (the salient features of a stimulus such as a limb on a body) instead of performing a full rotation. In this strategy participants choose a salient feature and then compare its position across the two stimuli in order to perform a match. Support for reliance on surface feature processing in ASD comes from Soulieres, et al. (2011), who examined mental rotation of geometric shapes, hands and letters in adults with ASD. They found that ASD participants showed faster and more accurate performance than TD participants on all stimulus types. However results also suggested that the participants with ASD had used the surface features of the stimuli during the task as opposed to performing a holistic rotation. These differences in the performance of mental rotation in autism have been attributed to weak central coherence (WCC) theory (Happe & Frith, 2006). WCC suggests that people with autism tend to focus more on the local features of a stimulus instead of processing it as a whole. This strategy is different to the configural strategy seen in TD people when performing mental rotation. Based on these previous studies, it is unclear how participants will perform in the mental rotation task. If they are able to perform mental rotation using a different strategy we may expect to see different patterns of response times (for example, they may not show the same linear relationship between response time and angular disparity that is usually seen in TD participants, but still display similar performance in regards to accuracy). However if mental rotation is intact in autism then we would not expect significant differences in regards to reaction times or accuracy.

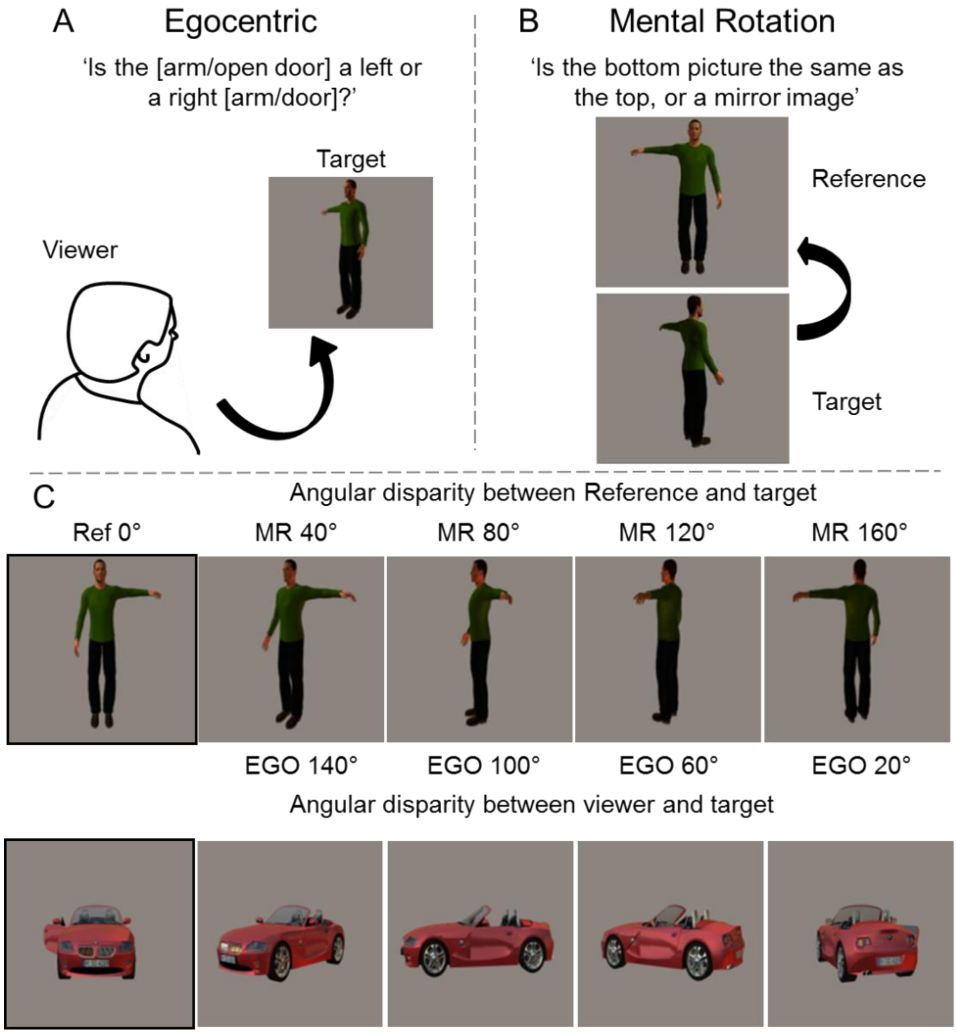

Figure 3.1 Elements present in the 2x2x2 design used in the current study. Figure 3.1A displays examples of stimuli and task demands for the egocentric task. Figure 3.1B shows examples of stimuli and task demands for the mental rotation task. 3.1C displays examples of the stimuli used in both tasks, and angular disparities.

Here the performance of a group of ASD adults is compared with a group of typically developing adults in a 2x2x2x4 factorial design looking at the effects of task (egocentric/mental rotation), group (ASD/Typical), stimulus form (body/car) and angular disparity (4 levels) on accuracy, reaction time, regression slopes and intercepts. Two different tasks are used, one to measure egocentric transformations and another to examine mental rotation. Here egocentric transformations are measured using laterality judgements (Fig 3.1A) and mental rotation is measured using a standard same/different (Fig 3.1B) mental rotation paradigm (Shepard & Metzler, 1971). In the egocentric the participants must decide whether the extended feature of the stimulus is a left/right feature (i.e. a right arm). Here, angular disparity is calculated in relation to the disparity between the viewer and the target (Fig 3.1A). In the mental rotation task (Fig 3.1B) the participant decides whether the target stimulus is the same as, or a mirror image of the reference object. Here, angular disparity is calculated between the reference stimulus and the target stimulus. The paradigm used in the current study is similar to that of Zacks (Zacks, et al., 2000; Zacks, et al., 2002), however, Zacks' study presented stimuli in the picture plane (rotations around a central vertical axis against the two dimensional flat surface on which the stimulus is presented). Depth plane (rotations around a vertical axis in the third dimension) rotations were used as these are most similar to rotations experienced in everyday life.

Both tasks use the same stimuli: a fully clothed human body with one extended arm and a car with an open door, both rotated in the depth plane (Fig 3.1C). The use of both bodies and objects allows us to ensure that any differences between groups are not simply a result of perceptual processing issues in the participants with autism. It has been argued that people with autism may be impaired at the processing of bodies compared to objects (Reed, et al., 2007). Thus, by testing both bodies and objects we can examine difficulties which are specific to both task and stimuli. If people with autism have particular difficulty with one type of stimuli then this will be shown in a group by form interaction within the task.

If participants with ASD have problems using the self as a reference frame (Carmody, et al., 2001) then we will expect to see impaired performance on the egocentric task compared to the mental rotation task. If the ASD participants have a general problem with spatial transformations then we will see impaired performance in both the egocentric and mental rotation tasks.

3.1 Method

3.1.1 Participants

Two groups of participants took part in this study. Eighteen adults with a diagnosis of ASD were recruited from schools, colleges, service providers and a participant database held by the autism research team at the University of Nottingham. They had a mean age of 19.7 years and 17 were male. All individuals with ASD had an independent previous diagnosis autism or autism spectrum disorder and they also completed module IV of the Autism Diagnostic Observation Schedule with a trained examiner (ADOS (Lord et al., 1989)). Four of the ASD participants did not meet cut-off for ASD on the ADOS; however as all had a previously confirmed independent diagnosis of autism or autism spectrum disorder they were included in the study. The comparison group consisted of eighteen typically developing participants. The typically developing participants were also recruited from schools and colleges. They had a mean age of 18.5 years and 17 were male. All participants completed the Autism Spectrum Quotient (AQ (Baron-Cohen, Wheelwright, Skinner, et al., 2001)). An independent samples t-test was used to examine whether groups differed significantly in regards to AQ scores. It was shown that, as expected the ASD group had significantly higher AQ scores than the TD group ($t(34)=4.55$, $p<0.001$). The Wechsler Adult Intelligence Scale (WAIS-IV: (Wechsler, 1981)) was used to assess participants’ cognitive ability (Full scale IQ, or FSIQ). There was no significant difference between the groups on this factor ($t(34)=-0.362$, $p=0.355$). Participants from both the ASD and typically developing groups met criteria for the experiment if they had a FSIQ of 70 or above and were aged 16 plus (Table 3.1). Participants were matched on age, gender and FSIQ (see Table 3.1). Five additional ASD participants completed the WAIS but were not included in the experiment as they failed to meet the cut-off point for inclusion. All participants in this study had normal or corrected to normal vision. This study was approved by the University of Nottingham ethics committee and all participants gave written informed consent prior to participating. All participants were compensated for their time.

Table 3.1: Descriptive Statistics for each group reported as mean ± S.D (range), with *t*-test results for group comparisons

	ASD	TD	T-test result
N	18	18	
Age	19.77±4.95 (16-32)	18.44±3.43 (16-29)	t(34)=.939,p=0.532
FSIQ	97.61±19.11 (70-132)	101.55±18.33 (76-139)	t(34)=-.632,p=0.355
VIQ	99.17±20.21 (71-143)	102.83±18.27 (80-142)	t(34)=-.571, p=0.571
PIQ	95.22±17.65 (69-136)	99±16.40 (75-127)	t(34)=-.665, p=0.510
AQ	26.5±6.98 (17-40)	16.61±6 (10-27)	t(34)=4.55,p=0.000
ADOS	10.6±4.24 (4-18)	-	-

3.1.2 Design

A 2x2x2x4 mixed design was used, with independent variables of task (egocentric and mental rotation), group (ASD and typical), stimulus form (body and car) and angular disparity (4 levels in each task). We measured the effect that these variables had upon accuracy (percentage correct) and reaction time (RT) in milliseconds. Each task had 2 blocks and each block consisted of 96 trials. Both order of task and block were counterbalanced across participants and order of trials within a block was randomised using the experimental software. The experiment was presented using Cogent (Wellcome Lab of Neurobiology) via Matlab 6.5 (Mathworks Inc.), which was used to collect and store the data.

3.1.3 Stimuli

The stimuli used were images of a fully clothed male body and a car, which were created using Poser 6. Each stimulus was depicted at 8 possible orientations (Fig 3.1C), varying in 40° increments from 40-160° clockwise and counter clockwise. Angular disparity in the mental rotation task was between the reference stimulus (which faced the participant) and the target stimulus. This gave angular disparities of +/- 40°, 80°, 120° and 160° in the mental rotation task. In the egocentric task, angular disparity was calculated between the participant’s own body and the stimulus (Fig 3.1A). This gave angular disparities of +/- 20°, 40°, 100° and 140° (Fig 3.1C) in the egocentric task. Both images were 250x250 pixels. In keeping with previous research (Zacks, et al., 2002) the body had either the left or right arm extended in each picture, and the car had the left or right door open. There were 16 body and 16 car stimuli (8 right and 8 left, one of each angular disparity). In the mental rotation task, there were 4 additional stimuli, two forward facing bodies and cars (one right, one left per stimulus type).

3.1.4 Procedure

Participants were tested individually either in the University lab, or a quiet area of their school/college. Testing was split into multiple sessions due to length (experimental tasks plus ADOS and WAIS). The WAIS and ADOS were completed first and then experimental data was collected in a separate session. Order of tasks was counterbalanced across participants as was block order. Participants performed two experimental tasks, one to measure egocentric transformations and the other to measure mental rotation. For the experimental tasks, all participants were seated in front of a computer screen at a distance of around 52cm. Both the mental rotation and egocentric transformations tasks involved spatial judgements about pictures of a fully clothed man and a car. Prior to the beginning of each task, participants were presented with a set of PowerPoint instructions detailing how to complete the task, then they completed a set of 20 practice trials with feedback to ensure that they understood instructions. After they had completed the practice trials and understood the task they began the experimental trials.

Participants completed two blocks in each task: a block of body stimuli and a block of car stimuli. For both tasks, once the trial image had appeared on screen, participants had a maximum of 10 seconds to respond. The next trial would begin after the participant had made a response or the allotted trial time (10 secs) had ended. No feedback was provided on the experimental trials.

In the egocentric task, participants had to make a decision about whether an extended arm/open door on the man/car was a left or a right arm or door (Fig 1A). One picture was presented with the angular disparity between the participant and the stimulus in the picture varying in 40° increments from 20°-140° clockwise and counter clockwise. Participants pressed ‘1’ to answer left (with their left hand) and ‘9’ to answer right (with their right hand) on the number line of the keyboard.

In the mental rotation task participants had to make a same/different judgement about pairs of stimuli, a paradigm used commonly in mental rotation and perspective taking experiments (Shepard & Metzler, 1971; Zacks, et al., 2000). Participants were presented with two pictures of a fully clothed body or a car and had to decide whether they were the same or mirror images (Fig 1B). The top picture always remained in the forward facing position and the bottom picture was shown at varying degrees of angular disparity (between 40-160°clockwise and counter clockwise in 40° increments). Participants responded by pressing ‘1’ if the pictures were the same and ‘9’ if they were different on the number line of the keyboard. Keys were labelled during the experiment to avoid confusion.

3.2 Results

Accuracy scores were computed by calculating how many correct trials each participant scored for each form/angular disparity and converting this into a percentage. Correct scores were collapsed across equivalent clockwise and counter clockwise disparities to give one value (i.e. trials for orientations +40° and -40° were combined into one variable) and then the mean value across trials calculated. Accuracy data was analysed using repeated measures ANOVA with group as a between subjects factor, resulting in the use of a mixed design.

Reaction times were calculated by finding the median reaction time (on correct trials only) for each participant for each angular disparity and form. Median values were used to reduce the impact of outliers. To calculate the value for each angular disparity equivalent clockwise and counter clockwise disparities were collapsed to give one value (i.e. trials for orientations +20° and -20° were combined into one variable). Reaction times were analysed using repeated measures ANOVA with group as a between subjects factor resulting in the use of a mixed design. Where sphericity has been violated Greenhouse Geisser corrected values are reported.

Previous studies (Falter, et al., 2008; Parsons, 1987; Shepard & Metzler, 1971) have used slopes and intercepts to further demonstrate the different processes involved in spatial transformations. Slopes are used as an indication of the strength of the rotation, a positive, steeper slope indicates that at that response time is strongly affected by angular disparity. Intercepts indicate how quick a participant would respond if there was no angular disparity between the stimuli and reference (congruent stimulus and reference positions). These are useful for examining general differences between groups which may be attributable to more general perceptual differences (Falter, et al., 2008).

A linear regression model was fit to the reaction time data for each participant with angular disparity entered as the independent variable and the slope and intercept of the regression recorded. A mixed ANOVA was used to examine the effects of task, form and group on slope and intercept.

3.2.1 Mental Rotation Results

Accuracy was examined in the mental rotation task using a repeated measures ANOVA with group entered as a between subjects factor. There was no significant effect of group ($F(1, 34) = 2.798$, $p=0.104$) or form ($F(1, 34) = 0.197$, $p=0.660$). There was a significant effect of angular disparity ($F(3,102) =6.77$, $p<0.001$). There was also a significant interaction between form and angular disparity ($F(3,102) =2.73$, $p=0.048$) insofar as accuracy decreased as angular disparity increased for the body stimuli but stayed stable for the car (Figure 3.2B). This suggests that mental rotation of bodies is harder at higher angular disparities. There was no significant interaction between form and group (F (1, 34) = 0.405, p=0.529), angular disparity and group (F (3, 102) = 0.444, p=0.722) or form, angular disparity and group (F (3, 102) =0.155, p=0.926).

Median reaction times in the mental rotation task were examined using a repeated measures ANOVA with group entered as a between subjects factor. There was a marginal effect of group on RT (F (1, 34) =4.52, p=0.054), with the ASD group showing marginally slower RT's (Figure 3.2A). There was no significant effect of form on reaction times (F (1, 34) = 1.330, p=0.257). There was a significant effect of angular disparity (F (3,102) =10.89, p<0.001), with RT's increasing as the angular disparity between the two stimuli increased. There was a significant interaction between group and angular disparity (F (3,102) =3.09, p=0.03) with the ASD group more strongly affected by increases in angular disparity than the typical group. There was also a significant interaction between form and angular disparity (F (3,102) =7.55, p<0.001), with a stronger linear relationship between angular disparity and RT for the body stimuli than for the car (Figure 3.2A).There was no interaction between group and form (p=.55) or group, form and angular disparity (F (3, 102) = 1.834, p= 0.146).

Slopes (a measure of the spatial transformation) in the mental rotation task were examined using a repeated measures ANOVA with group entered as a between subjects factor (Fig 3.2C). There was no significant effect of group (F (1, 34) = 1.161, p=0.289). There was a significant effect of form (F (1, 34) =15.19, p<0.001) with bodies showing more positive slopes than cars. This is reflected in the interaction between form and angular disparity for reaction times. There were no interactions between group and form (F (1, 34) = 0.409, p=0.527).

Intercept in the mental rotation task (a measure of perceptual processing was examined using a repeated measures ANOVA with group entered as a between subjects factor (Fig 3.2D). For intercepts there was a marginal effect of group (F (1, 34) =3.58, p<0.067) with the typical group showing marginally lower intercepts than the ASD group. There were no significant effects of form (F (1, 34) = 0.166, p=0.686) and no interactions between group and form (F (1, 34) = 0.506, p=0.504).

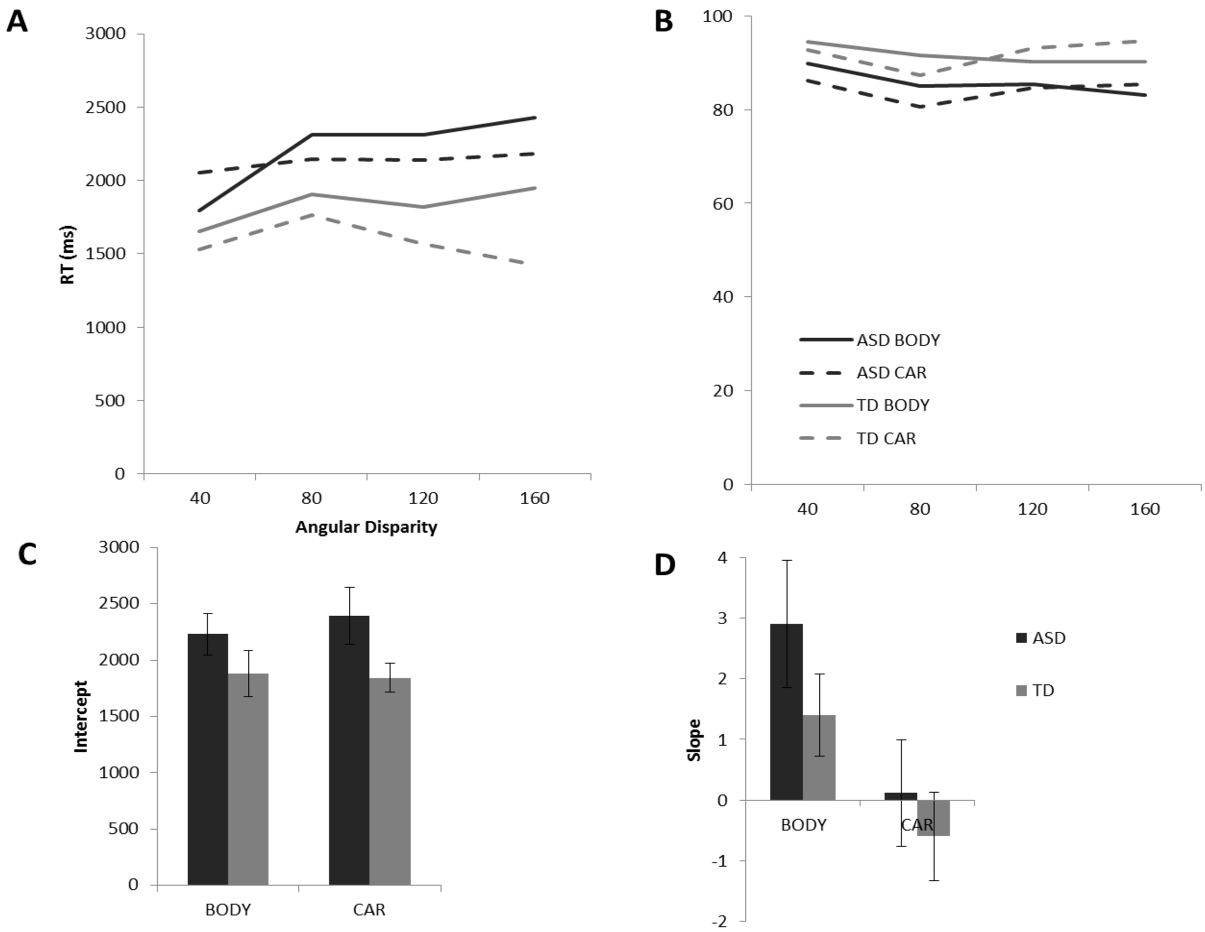

Figure 3.2A displays effect of angular disparity on RT in the mental rotation task for ASD and TD groups' performance on the body and car. **B** displays the effects of angular disparity on accuracy. **C** displays effects of group and form on intercepts with error bars to show S.E., and **D** displays effects of group and form on slope with error bars to show S.E.

3.2.2 Egocentric Results

Accuracy was examined in the egocentric task using a repeated measures ANOVA with group entered as a between subjects factor. There was a significant effect of group ($F(1, 34) = 4.65$, $p = 0.038$) with the ASD group less accurate than the typical group. There was no significant effect of form ($F(1, 34) = 0.514$, $p = 0.478$), but there was a significant effect of angular disparity ($F(3, 102) = 23.81$, $p < 0.001$) with accuracy increasing as angular disparity between the participant and stimuli decreased. There was a significant interaction between form and angular disparity ($F(3, 102) = 2.98$, $p = 0.04$) in that as angular disparity increased accuracy for the car decreased, but stayed relatively stable for the body. There was no interaction between form and group ($F(1, 34) = 0.081$, $p = 0.778$), angular disparity and group ($F(3, 102) = 1.281$, $p = 0.285$) or form, angular disparity and group ($F(3, 102) = 0.71$, $p = 0.975$).

Median reaction times in the egocentric task were examined using a repeated measures ANOVA with group entered as a between subjects factor. There was a significant effect of group ($F(1, 33) = 12.55$, $p = 0.001$) showing overall that the ASD group had slower RT's than the typical group (Fig 3.2A). There was no significant effect of form ($p = 0.88$) however there was a significant effect of angular disparity ($F(3, 99) = 47.46$, $p < 0.001$) with RT's increasing as angular disparity between the participant and the stimulus increased. There was an interaction between angular disparity and group ($F(3, 99) = 3.56$, p=0.049) with the ASD group more strongly affected by angular disparity than the typical group. There was no interaction between form and group (F (1, 33) = 0.938, p=0.340), form and angular disparity (F (3, 99) = 0.372, p=0.744) or form, angular disparity and group (F (3, 99) = 1.737, p= 0.164).

Slopes in the egocentric task (a measure of the spatial transformation) were examined using a repeated measures ANOVA with group entered as a between subjects factor (Fig 3.3C). The effect of group on regression slope was marginally significant (F (1, 34) =2.90, p=0.097) with the ASD group showing marginally more positive slopes than the typical group. This can be seen reflected in the reaction time data in the interaction between group and angular disparity. There was no significant effect of form (F (1, 34) = 0.166, p=0.686) and no interactions between form and group (F (1, 34) = 0.391, p=0.391).

Intercepts in the egocentric task (a measure of perceptual processing) were examined using a repeated measures ANOVA with group entered as a between subjects factor (Fig 3.3D). There was a significant effect of group (F (1, 34) =5.33, p=0.03) with the typical group showing significantly lower intercepts than the ASD group. These results are reflected in the significant effect of group on RT. There was no significant effect of form (F (1, 34) = 0.184, p=0.670) and no interactions between the two (F (1, 34) = 0.023, p=0.881).

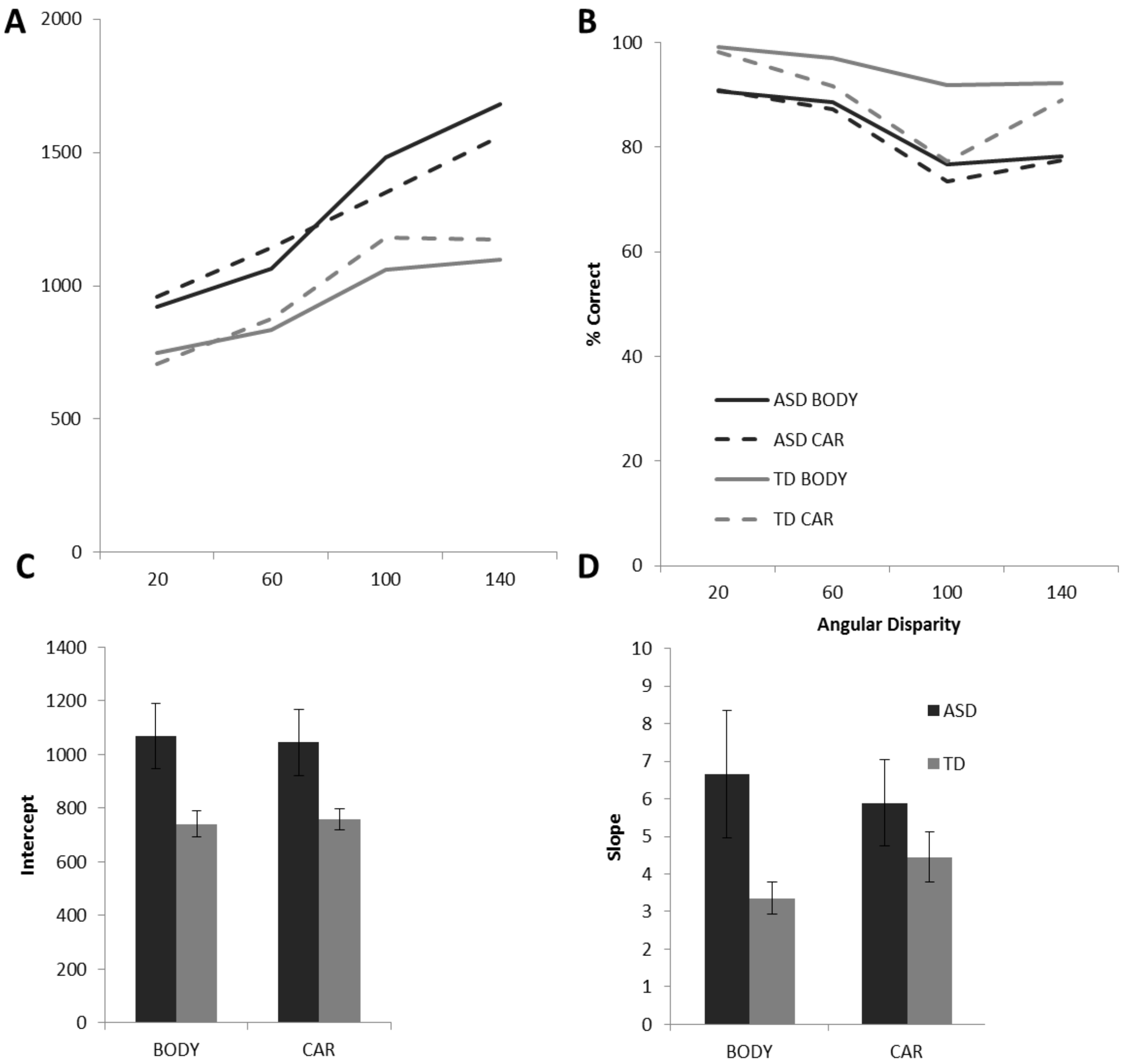

Figure 3.3A displays effect of Orientation on RT in the egocentric task for ASD and TD groups' performance on the body and car. **B** displays the effects of angular disparity on accuracy. **C** displays effects of group and form on intercepts with error bars to show S.E. and **D** displays effects of group and form on slope with error bars to show S.E.

3.2.3 Comparisons Across Tasks

In order to examine whether there were any differences in spatial ability and cognitive performance overall between egocentric transformations and mental rotation, slopes and intercepts were compared across tasks.

For slopes a repeated measures ANOVA with group as a between subjects factor showed that there was a significant effect of task (F (1, 34) =23.61, p<0.001) with steeper slopes in the egocentric task. There was also a significant effect of group (F (1, 34) = 4.13, p=0.05) with the ASD group showing steeper slopes than the typical group. There was a marginal effect of form (F (1, 34) =3.05, p=0.09) and a significant task by form interaction (F (1, 34) =8.65, p=0.006) with similar slopes between bodies and cars in the egocentric task but higher slopes for bodies compared to cars in the mental rotation task. There was no significant interaction between task and group (F (1, 34) = 0.419, p=0.522), form and group (F (1, 34) = 0.953, p=0.336) or task, form and group (F (1, 34) = 0.145, p=0.705).

For intercepts a repeated measures ANOVA with group as a between subjects factor showed that there was a significant effect of task (F (1, 34) = 107.6, p<0.001) with lower intercepts in the egocentric task. There was also a significant effect of group (F (1, 34) =5.99, p=0.02) with the typical group showing lower intercepts than the ASD group. There was no significant effect of form ($F (1, 34) = 0.353$, $p=0.556$) and there were no interactions between form and group ($F (1, 34) = 0.556$, $p=0.461$), task and group, ($F (1, 34) = 0.558$, $p=0.460$), task and form ($F (1, 34) = 0.037$, $p=0.848$) or task, form and group ($F (1, 34) = 0.272$, $p=0.605$).

3.3 Discussion

The current study aimed to investigate whether people with autism are able to perform different types of spatial transformation. Both egocentric transformations and mental rotation of bodies and objects were examined. The results showed that whilst people with autism were marginally slower than TD people but just as accurate at performing mental rotation, they were significantly slower and less accurate at performing egocentric transformations. There were also interesting effects of group on both slope and intercept suggesting more general impairment across spatial transformations in people with autism. First the results of each task are discussed, followed by examination of the across task comparisons and how they may provide evidence of a general perceptual impairment in autism.

Mental Rotation Task

In the mental rotation task there was a marginal effect of group (0.054) on response time but no significant effects of group on accuracy, showing that whilst the ASD group were slower to perform mental rotation compared to the TD participants, they were no less accurate. The effects of group on response time in this task will be discussed further in the section discussing across task comparisons, as it is thought relate to more general differences related to perceptual processing in ASD. There was no significant effect of group on slope; however there was a marginal effect of group on intercept with the ASD group showing marginally higher intercepts.

Higher intercepts in the ASD group are of particular interest in the mental rotation task. Previous research has shown a difference in regards to intercepts but not slopes in ASD and typical participants (Falter, et al., 2008). In Falter's study children with autism showed lower intercepts than typical children suggesting they were quicker to make decisions about rotated stimuli. In the current study Falter's finding that slopes for mental rotation were similar in typical and autistic participants were replicated. However participants with autism had marginally higher intercepts in the mental rotation task, which suggests that it took them longer to decide whether the stimuli were the same compared to the TD participants. The lower intercepts in Falters study indicated that the children with ASD were using a local feature based processing strategy, attributed to WCC. In the current study, the higher intercepts coupled with the slope data suggest that the participants with ASD were not using a feature based strategy and instead relying on configural processing. However the results did indicate that the use of a more configural strategy in the ASD participants resulted in slower response times. This suggests that people with ASD can use a configural processing strategy but it negatively affects how quickly they perform. These results are not necessarily incoherent with those of Falter, they simply suggest that participants with autism are able to use both configural and feature based processing to perform spatial transformations, with different strategies resulting in different intercepts. These findings are consistent with those of Behrmann et al. (2006) who found that people with autism were able to use a configural processing strategy in a face recognition task, but it slowed response times as a result.

The current study uses a paradigm similar to Falter's (Shepard & Metzler, 1971) but with different types of stimuli. In the current study a body and a car were used as stimuli whereas as Falter's (2008) study used meaningless geometric shapes. It is possible that previous findings of intercept differences in ASD in mental rotation could also be due to the type of stimulus used and that using more familiar stimuli prompts a different processing strategy. It has been shown that participants are more likely to use a configural processing strategy for familiar stimuli (Behrmann, et al., 2006; Logothetis & Sheinberg, 1996) which may explain why participants in the current study used a more configural as opposed to feature based method of processing. More research is needed into this area in autism using general everyday objects, as many studies on configural processing have focussed exclusively on faces (Behrmann, et al., 2006).

In the mental rotation task there was a significant effect of form on regression slope. It was predicted that participants would show positive slopes (increase in reaction time with increased angular disparity) for both the car and body stimuli across both the mental rotation and egocentric task. Surprisingly, this result was not found for the car stimuli in the mental rotation task. The slope for the ASD group was around zero and the typical group displayed a negative slope. These findings suggest that participants may not have been using a standard mental rotation strategy for the car stimulus. These results are not consistent with previous studies of mental rotation, which have shown that a linear increase in reaction time occurs with angular disparity in a variety of stimuli such as letters, limbs and meaningless geometric shapes (Kosslyn, et al., 1998; Parsons, 1987; Shepard & Metzler, 1971).

Several studies have shown a flat relationship between angular disparity and response time for more familiar everyday objects such as radios and phones (Yu & Zacks, 2010; Zacks & Tversky, 2005). However in these studies objects were presented in the picture plane as opposed to the depth plane rotations used in the current study. Therefore it is difficult to conclude whether our inconsistent findings for the car are a result of the plane of rotation or a feature of the car itself. Future research into mental rotation using a variety of everyday objects and different planes of rotation could really add weight to this topic.

Egocentric Transformations Task

In the egocentric task there was a significant effect of group on both response time and accuracy with the ASD group slower and less accurate than the TD group. As with the mental rotation task, the effects of group on response time will be discussed further in the section discussing comparisons across tasks in relation to perceptual processing in autism. The effects of group on response time across tasks is believed to relate to a more general impairment in perceptual processing in autism; however the effects of group on accuracy in the egocentric task suggest more specific difficulties with egocentric transformations alongside impairments arising from perceptual differences.

Reasons for specific difficulty in the egocentric task are currently unclear. It is possible that people with autism have a general difficulty with making judgements involving the self. Previous studies have shown that people with autism struggle when making self-referential judgements (Frith & de Vignemont, 2005; Lombardo et al., 2010), which has been related to an inability to properly distinguish between the self and others. The egocentric task required the participant to use the self as a reference point for performing a spatial transformation. A general difficulty with self-reference and distinguishing the self from the target would explain the particular difficulty with this task.

An alternative explanation for the ASD group's impaired performance in the egocentric task is that people with ASD have problems with laterality judgements and distinguishing their left from right. Previous studies into handedness in ASD have shown that many people with ASD are ambidextrous and may show an ambiguous handedness profile switching arbitrarily between left and right (Cornish & McManus, 1996; Soper et al., 1986). This could make it more difficult for them to make judgements about laterality due to confusion between left and right. Handedness was not equated across groups, seventeen out of the eighteen TD participants were right handed and 14 out of 18 of the ASD participants were right handed. Two of the ASD participants were left handed and two of the ASD participants reported ambidextrous handedness. I did not collect any data on handedness aside from self-reported hand dominance so I cannot rule out general problems with laterality having an effect on performance. In future this may be worth taking into consideration when using laterality tasks with ASD participants.

In summary, the results in the egocentric task suggest that people with autism have a specific difficulty with using the self as a reference frame in performing spatial transformations. It is likely that this impairment could impact on the ability to take another person's perspective by causing problems in the underlying step we use to put ourselves in someone else's place.

Comparisons across Tasks

Both reaction time data and slope data reflect how long it took participants to perform each transformation. Whilst response times reflect how long a participant took to make a response in the task, slopes reflect the change in response times with each change in angular disparity. Participants with ASD showed slower response times than typical participants across both tasks and both types of stimuli (a marginal effect of group was found in the mental rotation task and a significant effect of group was found in the egocentric task). There was also a significant interaction between angular disparity and group across both tasks. This interaction showed that for each increase in angular disparity, participants with autism took longer to respond. Across task comparisons revealed an overall effect of group on slope with the ASD groups exhibiting steeper slopes than the TD participants. These differences in slope and response time across groups can perhaps be best understood in regards to the literature on perceptual processing in autism. Previous research has shown that people with autism generally tend to exhibit slower response times than TD people on perceptual tasks (Calhoun & Mayes, 2005). Recent research found that people with autism were slower to make same/different judgement about faces and objects compared to TD people (Behrmann, et al., 2006). These findings are particularly relevant to performance in the mental rotation task in the current study but can also explain differences in the egocentric task. Slowed response times on perceptual tasks have been attributed to the way in which people with autism process stimuli. Typically developing people tend to process faces, bodies and objects in a configural way, taking into account the position of different parts in relation to each other. People with autism on the other hand have been argued to process stimuli in a more piecemeal fashion (Happe & Frith, 2006), focussing more on the local details of a stimulus. Though people with autism are able to process stimuli configurally, their bias towards the use of a local processing strategy impacts on this ability resulting in interference and slower response times (Behrmann, et al., 2006). The participants with autism in the current study demonstrated the same pattern of response times across tasks as the TD participants (increase in response time with increased angular disparity), which suggests that they were processing the stimuli in a similar way. If they had used a local processing strategy the relationship between angular disparity and response time would have been flat. It is likely that the higher response times and steeper slopes in the ASD participants are a reflection of their difficulty with the use of a configural processing strategy. This difficulty is consistent with predictions made by the theory of WCC (Happe & Frith, 2006) which suggests that people with autism have difficulty with performing configural processing as they tend to focus in on the local features of a stimulus. The results of the current study show that people with autism are able to use a configural processing strategy when necessary, but at a detriment to speed of response.

These findings may be particularly useful for explaining selective differences in the performance of participants with high levels of autistic traits on tasks examining egocentric transformations. Kessler and Wang (2012) found that participants with high levels of autistic traits were less likely to use an embodied egocentric transformation in a perspective taking task. In a similar task Brunye, et al. (2012) found that participants with high levels of autistic traits were able to use an embodied egocentric transformation, but that they were significantly slower than low autistic trait participants. Differences in perceptual processing would suggest that they favour a more feature based strategy (resulting in a flatter relationship between response time and angular disparity, as seen in Kessler and Wang (2012), but are able to use a configural strategy, leading to slower response times (as seen in Brunye, et al. (2012)). These results, along with those of the current study suggest that people with ASD or high levels of ASD traits can show selective differences in processing style depending on the task and instructions they are presented with.

Further evidence for a general perceptual impairment in the ASD group can be seen in the analysis of intercepts. This analysis was used to give an overall indication of how fast response times would be independent of the angular disparity of the stimulus. Across task comparisons revealed a main effect of group on intercept with the ASD group showing overall higher intercepts than the TD group. These results support the notion of a general perceptual impairment in autism. They show that even if there was no angular disparity between the stimulus and the reference, the ASD participants would still be slower to respond than the TD participants. This is consistent with the suggestion that people with autism show generally slower processing speeds independent of the stimulus (Calhoun & Mayes, 2005).

In summary, the effects of group on response times, slope and intercept analyses point to a general perceptual impairment in people with autism that may have impacted on performance across both the mental rotation and egocentric tasks.

3.4 Broader Implications

The results from this study provide a contribution to our understanding of spatial processing in autism. The use of a carefully controlled design allowed us to closely examine the effects that using different spatial tasks and stimuli can have on performance of spatial transformations in both autistic and typical participants. Though more research is needed to tease apart specific spatial difficulties from difficulty in perceptual processing, these results provide evidence of spatial and perceptual impairments in autism which could impact on the ability to put themselves in someone else’s place. Further research could focus on how spatial ability links explicitly to social skills and examine the correlation between performance on different spatial transformations and social ability.

4 Level 2 VPT in Typically Developing Children

Chapters Two and Three examined body representation and spatial transformations in people with ASD. They aimed to investigate whether there was any evidence of impairment in these processes which could contribute towards difficulty in perspective taking in autism. Results from chapter 2 found no significant differences in performance between groups on the body representation task, however as the groups differed significantly on verbal ability and age it was difficult to conclude whether the ASD participants were showing truly unimpaired performance. Chapter 3 demonstrated that people with autism are impaired at performing spatial transformations, particularly those related to using the self as a reference frame. The aim of the current chapter is to explicitly investigate how spatial transformations and body representation relate to VPT2. This chapter will focus on data from TD children only, before moving on to examine children with autism in Chapter 5.

VPT is defined as the ability to see the world from another person's perspective, taking into account what they see and how they see it (Flavell, 1977). This chapter will focus on level two VPT (VPT2), which is the ability to understand that two different people viewing a scene or object simultaneously do not necessarily see the same thing (Flavell, 1977). VPT2 is complex ability which draws upon multiple sources of information, such as the representation of other people, their bodies and the space around them (Kessler & Thomson, 2009; Surtees, Apperley, & Samson, In Press; Yu & Zacks, 2010). The current chapter has two aims. The first is to investigate the development of the two subtypes of VPT2 (VPT2 self and other) in TD children and examine whether these abilities are related. VPT2 self refers to the process by which one can imagine what a scene would look like if they were in another place, whereas VPT2 other refers to the taking of another person's perspective. In order to do this the cognitive processes which underlie VPT2 self and other will be examined to assess whether the mechanisms which predict them are the same. The second aim is to investigate more generally the mechanisms which predict VPT2 in TD children. This will form the foundation for moving on to explore these relationships in individuals with ASD in the following chapter.

In the introduction to this thesis, several studies of VPT2 were reviewed. The method used by Hamilton, et al. (2009) is of particular relevance to this chapter, as the studies reported will use a similar paradigm. Hamilton examined VPT2 alongside mental rotation and ToM in VMA matched TD and autistic children. In the VPT2 task children were presented with a toy on a turntable and asked to identify their own point of view on the answer sheet. The toy was then covered and a doll placed at another spot on the table. The child was asked to identify the view of the toy the doll would have when the pot was lifted. For the mental rotation task children were shown a toy on a turntable and asked to identify which picture on their answer sheet matched their current view. The toy was then covered and rotated and the child asked to identify which view they would see when the pot was lifted. Results showed that the children with ASD were significantly worse on the VPT2 trials compared to the typical children, but performed better on the mental rotation task. Interestingly, a regression analysis also showed that in the TD children VPT2 ability was strongly related to ToM performance and marginally related to mental rotation performance ($p=0.073$).

In Hamilton's task, children had to make a perspective judgement for another person. This is classified as altercentric perspective taking, or perspective taking for other (taking the perspective of another person, or VPT2 other). The majority of studies into VPT2 have used this method with children, asking them how another person would view a scene (Flavell, et al., 1981; Moll, Meltzoff, Merzsch, & Tomasello, 2013). However, an alternative method is to ask the participant to imagine *themselves* at a different point in space and ask what they would see (a transformation of one's *own* perspective, or VPT2 self). Several studies of VPT2 in adults have used this method (Schwabe, et al., 2009; Wraga, et al., 2005), which is classified as egocentric perspective taking (not to be confused with egocentric transformations) or perspective taking for self. Egocentric perspective taking should not be confused with egocentric transformations. Whereas an egocentric transformation is the underlying step used to put oneself in another place, egocentric perspective taking refers to imagining how something would *visually* appear if you were somewhere else.

There has been some debate as to whether these two subtypes of VPT2 are closely related processes or tap into different abilities.

Behavioural data seems to suggest that they might be closely related through the use of shared underlying cognitive processes (Kessler & Thomson, 2009). So far in this thesis the role of body representation and spatial transformations have been considered, however there has been no distinction made so far between those processes which may be involved in putting the self in another place versus putting oneself in someone else's place. It is possible that these subtypes rely on similar processes, however if this is to be discerned we must consider how VPT2 self and VPT2 other may differ.

Research has shown that a participant's reaction times increase the more incongruent the target viewpoint is from their own viewpoint in VPT2 (Kessler & Rutherford, 2010; Kessler & Thomson, 2009). This occurs regardless of whether a person has been asked to transform their own perspective or take someone else's perspective (Kessler & Thomson, 2009; Mazzarella, Ramsey, Conson, & Hamilton, 2013). Kessler and Thomson asked participants to make left/right decisions about an item on a table, either in relation to an avatar or an empty chair. They found that the same pattern or response times were displayed (slower responses when the angular disparity between the participant and target was higher) when making judgements for both. It is argued that this was a result of participants using the same whole body egocentric spatial transformation to complete both VPT2 self and other, either transforming themselves into the viewpoint of another person (VPT2 other) or the empty chair (VPT2 self) (Kessler & Thomson, 2009). This argument is logical considering that in order to take a different viewpoint one must transform from their position to a new one regardless of whether the end goal involves another person or just the self. Data from fMRI supports this notion, showing that VPT2 self and other engage similar brain regions (Mazzarella, et al., 2013) which tend to be involved in imagined rotations. However, this doesn't necessarily mean that there aren't differences in other underlying processes which may be involved in VPT2 self/other.

VPT2 other requires thinking about another person, whereas VPT2 self requires thinking about the self only. Though both could be used to inform social communication through imagining things from a different perspective, VPT2 other always occurs in a social context as it requires thinking about another person and their experience of the world. VPT2 self does not necessarily engage any social processes.

In Hamilton's study it was shown that VPT2 other (VPT2O) was strongly predicted by theory of mind performance and marginally by mental rotation. The contribution of ToM is not surprising as both ToM and VPT2O demand the simultaneous representation of two differing viewpoints (mental states in ToM and visual states in VPT2). Hamilton's finding of a strong relationship between VPT2O and ToM is likely to tap into this simultaneous representation. These findings are also consistent with the suggestion made in the introduction to this thesis that those people who are better at seeing things from another person's visual point of view are likely to be better at social interaction and understanding other's mental states.

However, it is unclear whether ToM and VPT2S will be as strongly related as ToM and VPT2O. Some researchers have argued that representing one's own current and past/future mental states does not require the same processes as representing one's own current mental state and the current mental state of another person (Gopnik & Wellman, 1992). Whilst the mental state of oneself can simultaneously occur in conjunction with that of another, there must be a change between one's own current mental state and future mental state, i.e. 'I want chocolate and Cindy wants coffee' is different to 'I want chocolate now but later I will no longer be hungry and instead will want coffee' (i.e. they are mutually exclusive). If this was the case for VPT2S then it is possible that it might not be related to ToM in the same way as VPT2O.

However, for visual information this mutual exclusivity need not be the case. For example 'I can see the front of the cereal box and Cindy can see the back' and 'I can see the front of the cereal box and if I sat at the other side of the table I would see the back of the cereal box' can both occur in conjunction. Thus still requiring simultaneous representations in a similar way to ToM.

Further to the relationship between ToM and VPT2O in children, the adult literature on VPT2 has shown that general social skills are predictive of perspective taking ability in TD adults. Recent research has shown that TD adults with higher autistic traits (measured using the AQ) demonstrate difficulty with performing perspective transformations (Brunye, et al., 2012; Kessler & Wang, 2012; Shelton, et al., 2012). These findings point to poor perspective taking being linked to real world social interaction ability.

In the current study the relationship between social ability and VPT2S will be examined. The SAS will be used as a proxy for ToM, as it is possible that using a group of TD children who are all above the age at which children are expected to pass ToM tests could lead to a general ceiling effect in ToM performance which could prevent a relationship between ToM and VPT2S being observed. By using a measure of social skills it is more likely that a spread of ability will be seen and will highlight a relationship with VPT2S if one is present.

It is also possible that both VPT2 self and other may be reliant on general rotational abilities. In Hamilton's study it was found that VPT2O was marginally predicted by mental rotation ability in the TD children. Mental rotation (MR) is the process by which we can manipulate the orientation of images in our minds (Shepard & Metzler, 1971; Wraga, et al., 2003) and are able to compare two objects from different viewpoints. It has been shown that children become accurate at performing mental rotation by around age 8 years old, though children as young as 5 display the linear relationship between response times and angular disparity that is found in adults (Kail, Pellegrino, & Carter, 1980). Based on previous behavioural research we would not necessarily expect to find a relationship between either subtype of VPT2 and mental rotation, as it has been shown that egocentric transformations are the process used by TD people transform viewpoints in VPT2 (Yu & Zacks, 2010). However, it is possible that good mental rotation skills could contribute towards perspective taking ability by allowing participants to use an alternative strategy for rotating a scene. Though this method is generally seen as a less efficient way of completing VPT2 it can still result in an accurate response (Zacks and Tversky 2005). Thus findings from Hamilton et al. (2009) warrant further investigation in order to examine whether the relationship between mental rotation and VPT2 ability goes further than would be expected on the basis of previous research. Mazzarella et al. (2013) found that VPT2 self led to stronger activations in areas associated with self rotations than VPT2 other. The authors related this finding to the stability of landmarks during each task and the possible differences in processes used to code the position of other people and objects in the environment. However, these findings do not necessarily indicate that VPT2 other may be more reliant on general spatial abilities, but may simply indicate additional processes used to code the position of stimuli other than the self. The studies in this chapter will investigate the relationship between mental rotation and both subtypes of VPT2 ability.

Another possible contributing factor in both VPT2 self and other is the ability to represent bodies from different points of view. This ability would provide information which can aid VPT2, for example the orientation of a person's head can provide knowledge on what they can see. Body representation could also contribute towards perspective taking through providing the means to represent the bodies around us from different points of view. Grush (2004) suggested that we transform perspectives by first creating a motor representation of the target body, and then transforming ourselves to match the target. This is consistent with literature on the involvement of embodied egocentric transformations in VPT (Kessler & Thomson, 2009; Parsons, 1987; Schwabe, et al., 2009; Zacks & Tversky, 2005). Being more proficient at body representation would make it easier to form a representation of the target prior to transforming viewpoints. Drawing on previous research showing that both VPT2 self and other appear to rely on the ability to perform egocentric body transformations (Kessler and Thomson, 2009), it is likely that both subtypes may have a relationship to body representation skills. So far there has been little investigation into whether there is an explicit relationship between the representation of bodies and VPT2 performance. Thus, the second experiment in this chapter will consider the relationship between VPT2 and body representation in TD children.

Finally, at the most basic level we know that a child's age and verbal ability can be predictive of their performance on cognitive tasks

(Happe, 1993). Research has shown that verbal ability predicts perspective taking in TD children (Farrant, et al., 2006). As verbal ability increases in line with age in TD children it is also reasonable to assume that age will predict VPT2. In order to examine the relationship between age and verbal ability and VPT2, a developmental trajectory approach will then be applied to the data. Large groups of children will be tested and performance on each task will be plotted separately against age and verbal ability. This will allow for examination of how the different processes develop across childhood. This will provide the basis to examine any differences in development between the typical and autistic children. In the current study standardised BPVS scores will be used as a measure of verbal ability. Standardised scores are used as opposed to raw scores as raw BPVS scores and age are highly correlated in TD children, meaning the two variables are often seen as a measure of the same factor.

Two experiments are reported in this chapter. The first expands on methods used by Hamilton et al. to examine VPT2 self (‘what would you see if you were sitting over there?’) in TD children. It will investigate whether VPT2 self, mental rotation and social ability are related. The second study will examine both VPT2 self and other in order to assess how closely related these abilities may be. This experiment will also investigate the relationship between both subtypes of VPT2 and body representation, mental rotation and social skills. It is predicted that body representation will be a stronger predictor of VPT2 in TD children than mental rotation.

4.1 Experiment 3

Experiment 3 will examine VPT2S, mental rotation and social skills in TD children. It is expected that VPT2S may be marginally related to mental rotation ability as found in Hamilton and colleagues study of VPT2O. Hamilton and colleagues also found that ToM was predictive of VPT2O ability. It is expected that in the current experiment VPT2S may be related to social skills which are being used here as a proxy for ToM.

4.2 Method

4.2.1 Participants

A total of 89 children participated in this study (Table 4.1) including 12 four year olds, 15 five year olds, 19 six year olds, 15 seven year olds, 7 eight year olds, 8 nine year olds and 5 ten year olds. The children were recruited during Nottingham University's Summer Scientist Week, an event designed to recruit children to take part in various studies in the form of short "games". All children completed the BPVS and their parent/caregiver also completed the SAS (Liddle, et al., 2009) to give an indication of their social ability. None of the typical children had a diagnosis of ASD or any other learning difficulty, confirmed by parent questionnaire.

All parents of participating children and their schools consented to taking part in the study, which was approved by The University of Nottingham ethics committee. Each child was tested individually in a partitioned cubicle in a room set up for the Summer Scientist data collection.

Table 4.1: Participant demographics with Mean ± S.D (range)

N	Age	BPVS Raw	BPVS Standardised	SAS
89	6.87±1.78	78.77±20.44	110.37±14.39	24.59±5.47
	(4.07-10.74)	(20-122)	(54-144)	(7-39)

4.2.2 Design

A repeated measures design was used in which each child completed two tasks: one mental rotation (MR) task and one VPT2S task. In each task there were 4 different viewpoints that the stimulus could be shown from: front, back, left and right (Figure 4.1e). For each task performance was measured by calculating how many trials a child got correct (their accuracy). Each child performed 24 trials each for the VPT2S task and 24 trials for the MR task (6 per viewpoint) equalling 48 trials in total. Viewpoints were tested in a pseudorandom order. Block order was counterbalanced across children. Each correct response received a score of 1 giving a maximum score of 24 per task.

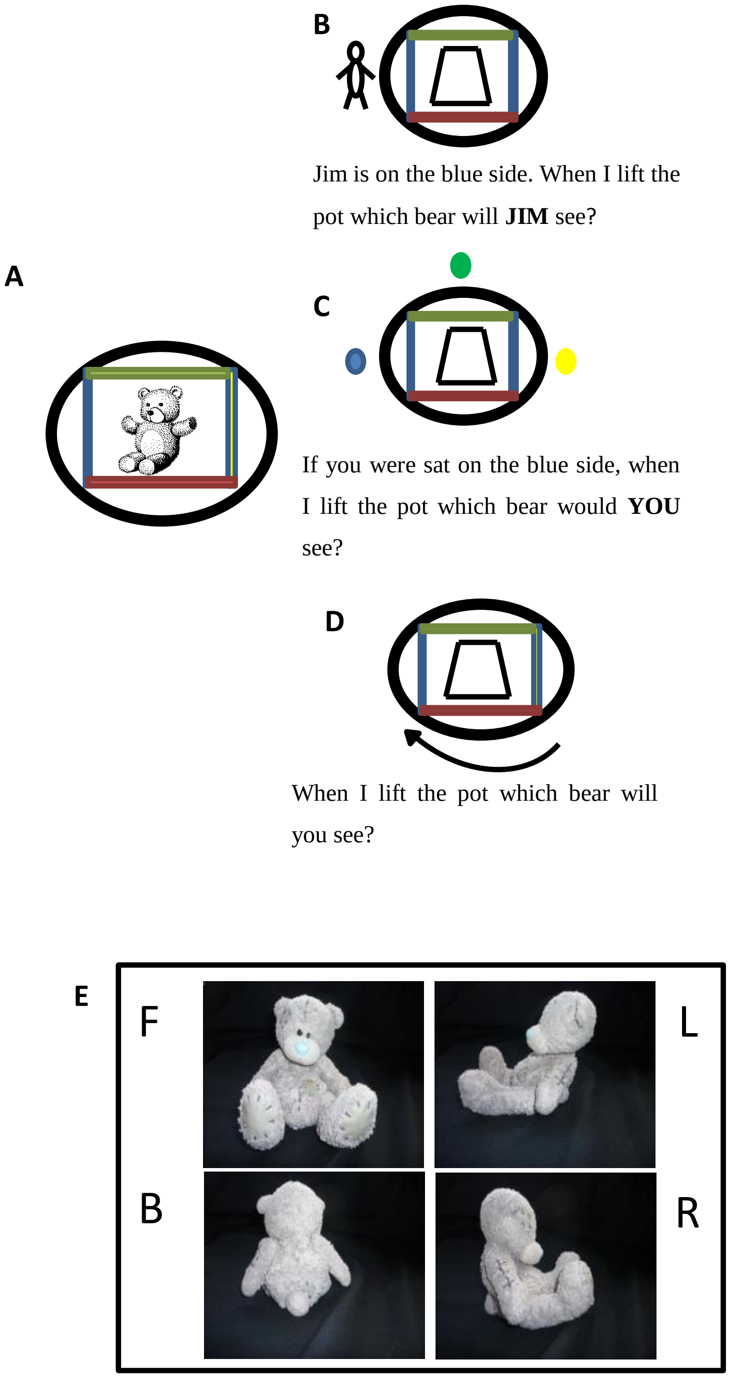

Figure 4.1: Examples of stimuli and tasks. **A** depicts the toy place on the turntable. The toy is then covered. **B** depicts VPT2O: What will JIM see? (Experiment 4 only) **C** depicts VPT2S: What will YOU see? **D** depicts the mental rotation task, in which the toy is rotated and the child is asked which view they will see when the pot is lifted. **E** displays an example of a response card given to the child.

4.2.3 Materials

The materials for the VPT2S and MR tasks were a small turntable, an opaque pot and three toys. The turntable had a coloured strip running along each side to form a square in which to place the toy. The toy used was a teddy bear. The corresponding answer sheet displayed four pictures of the toy, shown from the viewpoints of front, behind, left and right (Figure 4.1)

4.2.4 Procedure

For both the MR and VPT2S task, the child sat at a table with the experimenter. The VPT2S task was designed to measure the ability to consider what the child themselves would see if they were sitting at a different location. For this task the toy was placed upon the turntable facing one of the coloured strips. The child was presented with a picture card showing four images of the toy from different viewpoints. At the start of each trial, the child was asked 'which picture can you see?'(Figure 4.1a). This established the initial orientation of the toy and that the child was attending to the toy. The toy was then covered with an opaque pot and the child asked 'if you were sitting at the [blue] side of the table (there were also coloured stickers on the appropriate table sides), which picture would you see when I lift up the pot?' (Figure 4.1c)

Other colours were substituted as appropriate, to test all 3 alternative viewpoints.

For the MR task, a toy was placed upon the small turntable facing one of the coloured strips. At the start of each trial the child was asked ‘which picture can you see’ to establish the initial orientation of the toy and that the child was attending to the toy. The toy was then covered with an opaque pot, and rotated to a different orientation. The child was then asked ‘when I lift the pot up, which picture will you see?’ (Figure 1d). For both the MR and VPT2S task, the child could respond by selecting the corresponding picture on the answer card.

4.3 Results

Data was collapsed across each rotation to give a single score out of 24 for each child, which was converted into a percentage. First, the performance on the VPT2S and MR task was analysed using an ANCOVA with variables of task (MR and VPT2S) and covariates of age, standardised BPVS and SAS. There was a significant effect of task ($F(1, 79) = 15.27$, $p<0.001$), with children performing better on the MR task as found in Hamilton et al. (2009). Age significantly predicted performance ($F(1, 79) = 103.62$, $p<0.001$) with older children scoring better on both tasks. There was no significant effect of SAS score ($F(1, 79) = 0.466$, $p=.0497$) or standardised BPVS ($F(1, 79) = 0.085$, $p= 0.771$). There were also no interactions between task and age ($F(1, 79) = 0.259$, $p= 0.612$), task and SAS ($F(1, 79) = 0.116$, $p=0.735$) or task and standardised BPVS score ($F(1, 79) = 2.452$, $p=0.121$).

Table 4.2: Participant demographics with Mean ± S.D (range)

Mental Rotation	VPT2S
68.59±21.14	58.06±25.58
(20.83-100)	(8.35-95.83)

4.3.1 Developmental Trajectories

In order to examine how VPT2S and MR change in relation to age and verbal ability score, the developmental trajectory for each task was plotted separately against age and BPVS standardised score. It can be seen in Figure 4.2 that both MR and VPT2S follow a linear trajectory with age in TD children, with performance increasing throughout childhood.

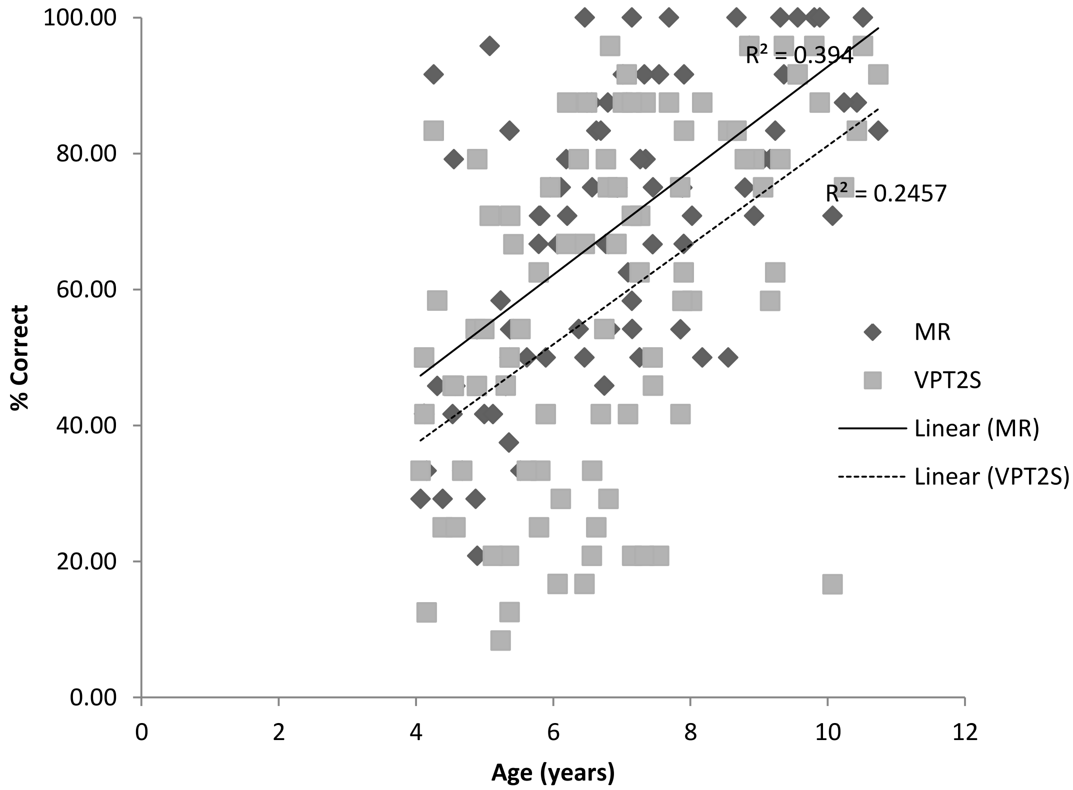

Figure 4.2: Developmental Trajectories for the development of mental rotation and VPT2S alongside age with each child shown as one data point.

However, Figure 4.3 shows that whereas VPT2S ability also increases linearly alongside verbal ability, the development of mental rotation ability follows a different trajectory. In Figure 4.3 below it can be seen that MR does not increase as verbal ability increases, but follows a much flatter trajectory.

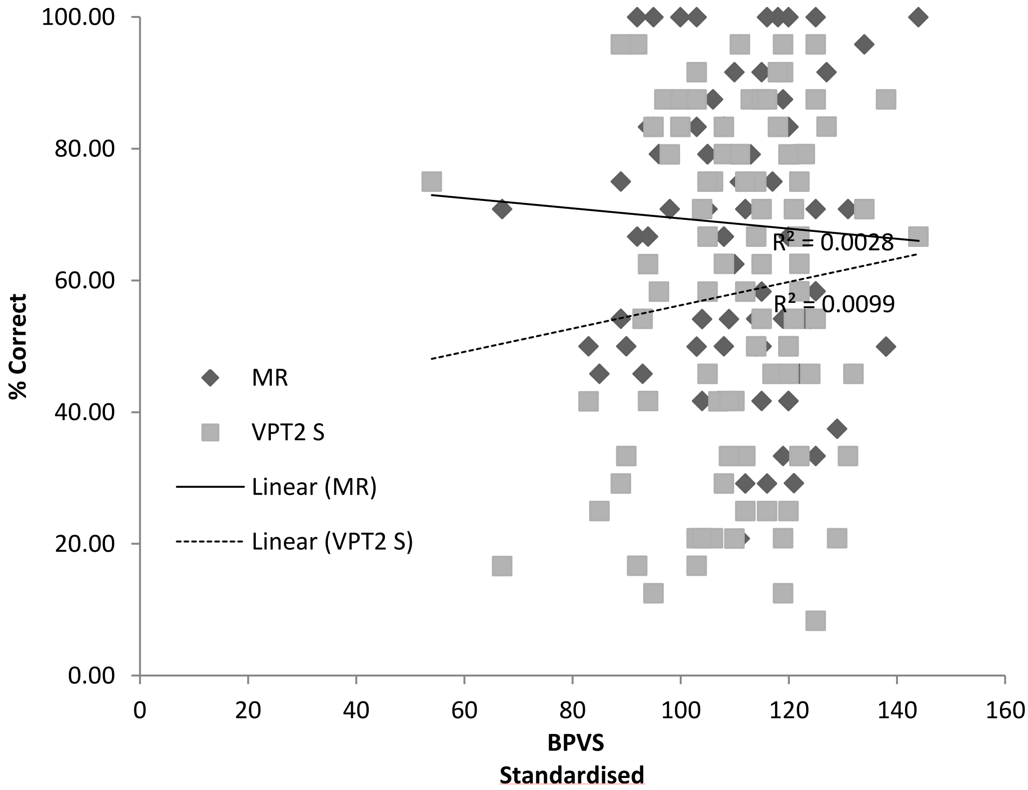

Figure 4.3: Developmental Trajectories for the development of mental rotation and VPT2S alongside BPVS standardised score with each child shown as one data point.

4.3.2 Regression Analysis

The developmental trajectory analysis showed that in relation to age VPT2S and MR showed a similar pattern of development, whereas in relation to BPVS the trajectories differed. In Hamilton's study it was shown that MR ability marginally predicted VPT2O ability, thus a regression analysis was conducted in order to assess whether VPT2S and MR would be related in the current study. Regression analyses were used to examine whether VPT2S performance was predicted by mental rotation ability, after controlling for age and verbal ability.

A two-step enter method was used to examine this relationship. At step one, age and MR were entered as the independent variables. The overall model fit was $R^2=.32$. Age significantly predicted VPT2S ($\beta=.414$, $p=0.003$) and BPVS standardised score did not ($\beta=.193$, $p=.161$). Mental rotation was entered at step two. The overall model fit was $R^2=.33$. Mental rotation did not significantly predict performance on VPT2 after controlling for age and verbal ability ($\beta=.086$, $p=.501$).

4.4 Conclusions

The results of this experiment showed that TD children were better at mental rotation than VPT2S, though performance was not at ceiling for either. These findings are consistent with Hamilton et al. (2009) who found that children around 6 years old responded accurately on the mental rotation and VPT2 tasks on around 50-60% of trials in their task. Previous research has shown social skills to be a predictor of VPT2O in adults (Shelton, et al., 2012). There was no significant effect of SAS on performance, however, only 4 of the children tested scored below 16, which is the cut-off for low social ability, usually associated with autism or autistic traits (Liddle, et al., 2009). It is possible that a lack of an effect from SAS may have been related to little variability in scores amongst the TD children. This result will be discussed further in the general discussion to this chapter. The regression analysis showed that VPT2S is not predicted by mental rotation performance. This is similar to Hamilton's study which found that mental rotation only made a marginal contribution ($p=0.073$) to explaining performance on VPT2O. Experiment four will examine both VPT2S and VPT2O, investigating whether the same processes predict each one and whether they are related. This study will investigate the relationship between mental rotation, body representation, social skills and age and verbal ability and both subtypes of VPT2.

4.5 Experiment 4

The aim of this experiment was to examine the cognitive processes which may be related to VPT2S and O in TD children. The previous study showed that mental rotation does not predict VPT2S, prompting the question of what *does* predict VPT2 performance. The current study will examine both VPT2S and O, asking firstly whether the two are related and secondly, whether body representation skills predicts performance in either. It is predicted that VPT2 S and O will be highly related, as previous research has shown that they appear to be driven by the same processes (Mazzarella, Hamilton, Trojano, Mastromauro, & Conson, 2012). As such, it is also predicted that body representation will be related to performance in both VPT2 S and O, and that (as shown in the previous study) mental rotation will not.

4.6 Method

4.6.1 Participants

A total of 76 typically developing children (mean chronological age: 6.16) completed this study (Table 4.3) including 22 four year olds, 21 five year olds, 17 six year olds, 6 seven year olds, 4 eight year olds, 3 nine year olds and 2 ten year olds and 1 eleven year old. The children were recruited during Nottingham University's Summer Scientist Week, an event designed to recruit children to take part in various studies in the form of short “games”. All TD children completed the BPVS and their parent/caregiver completed the SAS (Liddle, et al., 2009). None of the typical children had a diagnosis of ASD or any other learning difficulty, confirmed by parent questionnaire.

All parents of participating children and their schools consented to taking part in the study, which was approved by The University of Nottingham ethics committee. Each child was tested individually. The ASD children were tested in a quiet room in his or her own school or home, whereas the typically developing children were tested in a quiet, partitioned cubicle in a room set up for the Summer Scientist data collection.

Table 4.3: Participant demographics with Mean ± S.D (range)

	N	Age	VMA	BPVS Raw	BPVS Standardised	SCQ	SAS
TD ALL	76	6.17+1.62	6.79±1.62	71.65±20.86	109.9±13.09	-	24.6±5.31
		(4.03-11.35)	(3.03-13.06)	(33-120)	(62-138)		(13-39)

4.6.2 Design

A repeated measures design was used to examine the effects of task on performance. Each child completed four tasks (MR, VPT2S, VPT2O and body representation) and performance on each task was measured by calculating number of trials correct, which was transformed into a percentage. Additionally, all 76 children completed a VPT1 task; however the data from that task is not discussed here, and is instead outlined in Chapter 6. Each child performed 6 trials each for the VPT S task, VPTO task MR task and 12 trials for the body representation task (6 meaningful and 6 meaningless). In the VPT2S, VPT2O and MR tasks the six trials presented were a selection of the four different viewpoints in a pseudo randomised order (each child was tested on one of each viewpoint and then two randomly chosen viewpoints were counterbalanced across children). For the body representation task the order of trials within a block was pseudo randomised across children and the order of blocks (meaningful and meaningless) was counterbalanced. The order in which all tasks were presented was also counterbalanced across children.

4.6.3 Materials

The materials for the both of the VPT2 and the MR task were a small turntable, an opaque pot and three toys (a bear, a frog and a small fire truck). The turntable had a coloured strip running along each side to form a square in which to place the toy (See Figure 4.1). The order in which the toys were presented and which toy was used in each task was pseudo-randomised across children.

For the body representation task, the body stimuli from Chapter 2 were used. Only bodies were included in this study; hands and objects were not included. There were two sets of stimuli, a set of meaningful (MF) body postures and a set of meaningless (ML) body postures. For each trial there were two cards, one depicting two body postures (one target match and one foil) and one depicting an exemplar to be matched (Figure 4.4).

Figure 4.4: Example of a trial in the body representation task. The child is presented with a double card containing the target and foil and then asked to match the exemplar picture to the target.

4.6.4 Procedure

There were two VPT2 tasks and one MR task. For the VPT2S (Figure 4.1c) and MR (Figure 4.1d) tasks the same procedure as Study 1 was used (Figure 4.1). For the VPT2O task, the first part of the trial was identical to the VPT2S trial in that the child was presented with the toy on the turntable and asked to establish its initial orientation. The toy was then covered with the opaque pot. Once the toy was covered, a doll was placed at another side of the table, and the child was asked, ‘Jim is sitting on the [blue] side of the table, when I lift the pot up which picture will Jim see?’(Figure 4.1b)

For the body representation task, the child sat at a desk next to the experimenter. On each trial, the child was given a laminated card with two pictures (the target and foil) and told “here are two pictures”. Then the experimenter gave the child a second laminated card with a single picture (the exemplar) and said “Here is another picture, which one of these (point to double picture card) matches your picture?” The child could respond verbally, or by pointing or putting the single card with the appropriate match. The first trial was given as a practice trial, and any errors the child made were corrected with an explanation. After the child understood the task, the experimenter presented the 12 experimental trials, 6 meaningful bodies, and 6 meaningless. Praise was given throughout regardless of response.

4.7 Results

The number of trials that each child scored correct out of 6 was calculated and this number converted into a percentage. Performance across MR and VPT2S and VPT2O were examined using an ANCOVA with variables of task (MR, VPT2O and VPT2S) and covariates of BPVS standardised score and SAS. There was a significant effect of task ($F(2, 150) = 7.46$, $p = 0.001$), with children performing better on the VPT2 tasks than on the MR task. Age significantly predicted performance ($F(1, 75) = 67.67$, $p < 0.001$) with older children scoring higher. There was also a significant interaction between age and task ($F(2, 150) = 9.53$, $p < 0.001$) with a higher increase in accuracy with age in both VPT2 tasks compared to MR. There was no significant effect of SAS ($F(1, 75) = 0.000$, $p = 0.997$) or BPVS standardised score ($F(1, 75) = 0.301$, $p = 0.585$) and no interactions between task and BPVS standardised score ($F(2, 150) = 1.769$, $p = 0.174$) or task and SAS ($F(2, 150) = 0.361$, $p = 0.698$).

Table 4.4: Participant demographics with Mean ± S.D (range)

Mental Rotation	VPT2S	VPT2O
38±20.75 (0-100)	46.3±30.97 (0-100)	45.76±26.04 (0-100)

4.7.1 Specific Processes Underlying VPT2S and VPT2O

Regression analyses were used to selectively test which measures predicted VPT2 S and O performance in the typical children. Enter method was used for all regression analyses detailed. Data for the 76 TD children who completed the experiment were entered into a multiple linear regression model to determine which factors out of mental rotation, body representation, SAS, BPVS standardised and age predicted VPT2 S and O ability separately. For VPT2S the regression model had an overall model fit of R^2=.49. Results showed that performance on VPT2 S was significantly predicted by age (β=.430, p<0.001) and body representation (β=.302, p=.004), but not BPVS standardised score (p=0.102), SAS score (p=0.523) or MR (p=0.427). For VPT2 O the regression model had an overall model fit of R^2=.45. Results showed that performance on VPT2 O was significantly predicted by age (β=.538, p<0.001) and body representation (β=.228, p=.033) but not BPVS standardised score (p=0.532), SAS score (p=0.628) or MR score (p=0.597).

As VPT2 self and other were predicted by similar processes, the next aim was to examine how closely VPT2S and VPT2O were related. A bivariate correlation was performed, with age, BPVS standardised score, VPT2O and VPT2S as inputs. This showed that both tasks were highly correlated (r=.63, p<0.001), as were VPT2 S & O and BPVS. In order to examine whether VPT2 S & O were still correlated after accounting for BPVS a partial correlation was conducted. Results showed that after controlling for BPVS, both VPT2 tasks were highly correlated ($r=.503$, $p<0.005$). As both processes were so similar, VPT2S and VPT2O were averaged together to give a single VPT2 score for each child and a regression analysis examining the overall predictors of VPT2 in TD children was conducted.

4.7.2 What Predicts VPT2 Overall in TD Children

Regression analyses were used to test which measures predicted overall VPT2 performance in the typical children. Enter method was used for all regression analyses detailed in this chapter. Data for the 76 TD children who completed the experiment were entered into a multiple linear regression model to determine which factors out of mental rotation, posture representation, SAS, BPVS and age predicted VPT2 ability. The regression model had an overall model fit of $R^2=.56$. Results showed that in the typical group, performance on VPT2 was significantly predicted by age ($\beta=.530$, $p<.001$) and body representation ($\beta=.296$, $p=.002$). There was no significant effect of BPVS Standardised ($p=0.152$), SAS ($p=0.876$) or MR ($p=0.809$).

4.7.3 Body Representation Task

An ANCOVA was used to examine the effect of stimulus (MF/ML) category on accuracy, with BPVS and SAS entered as covariates. There was a significant effect of meaning (F (1, 76) = 22.92, p<0.001) with children showing higher accuracy for the meaningless stimuli, this is consistent with the findings in chapter 2. There was no significant effect of BPVS standardised (p=0.715) and no significant effect of SAS (p=0.321) and no interactions between meaning and BPVS score (p=0.717) or meaning and SAS (p=0.529).

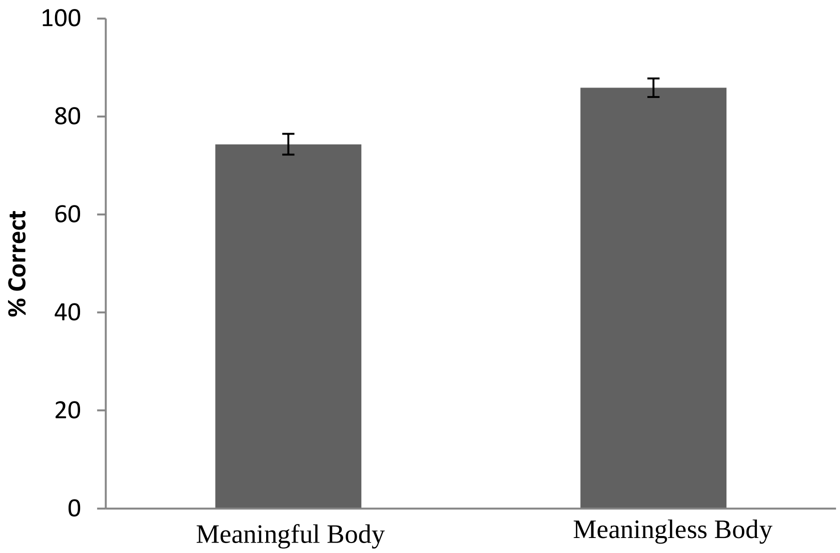

Figure 4.5: Mean performance (with S.E) on the body representation task. Accuracy was higher in the meaningless condition compared to the meaningful condition.

4.7.4 Developmental Trajectories

In order to examine how the different processes examined in this study (MR, VPT2S, VPT2O and body representation) change in relation to age and verbal ability, the developmental trajectory for each task was plotted separately against age and BPVS standardised score.

Both VPT2S and VPT2O show a steep linear increase with age, as does body representation with performance reaching the highest levels of accuracy at around 10 years old in all 3 tasks (Figure 4.6). Mental rotation however shows a much more subtle linear slope, with even the oldest children still not reaching ceiling on this task. This suggests that mental rotation develops more slowly than the other abilities in TD children in relation to age.

For verbal ability, all processes (VPT2S, VPT2O, MR and body representation) show a linear increase in performance with BPVS standardised score (Figure 4.7). Body representation is the most well developed ability in relation to BPVS, with higher scoring children showing performance closer to ceiling level on this task.

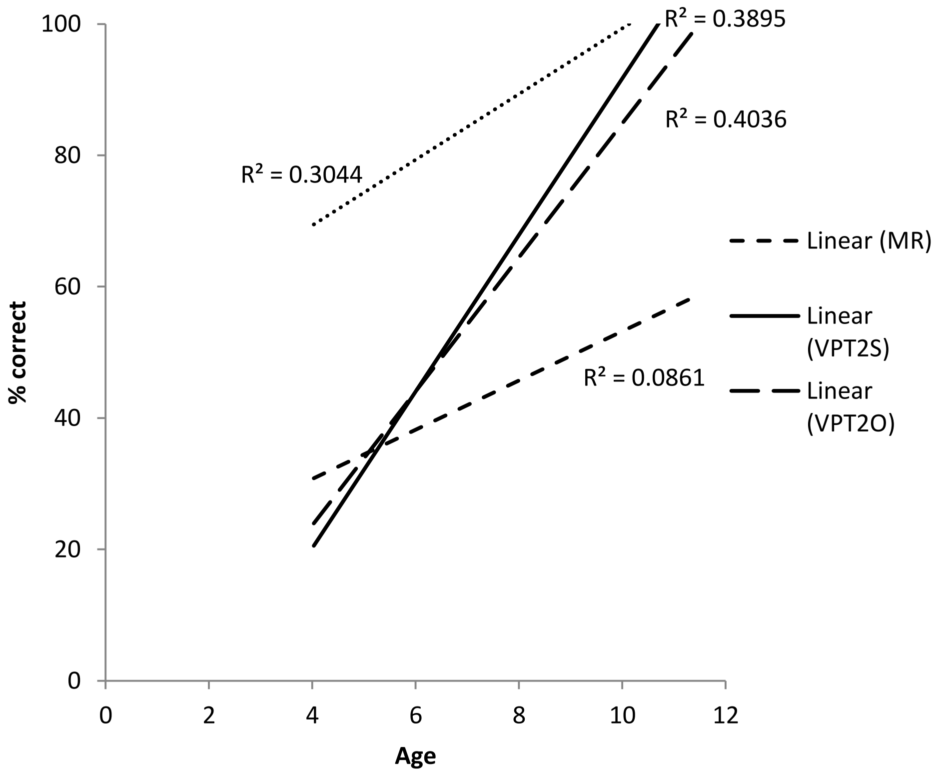

Figure 4.6: Developmental Trajectories for the development of mental rotation, VPT2S & O and Body representation across children plotted against age.

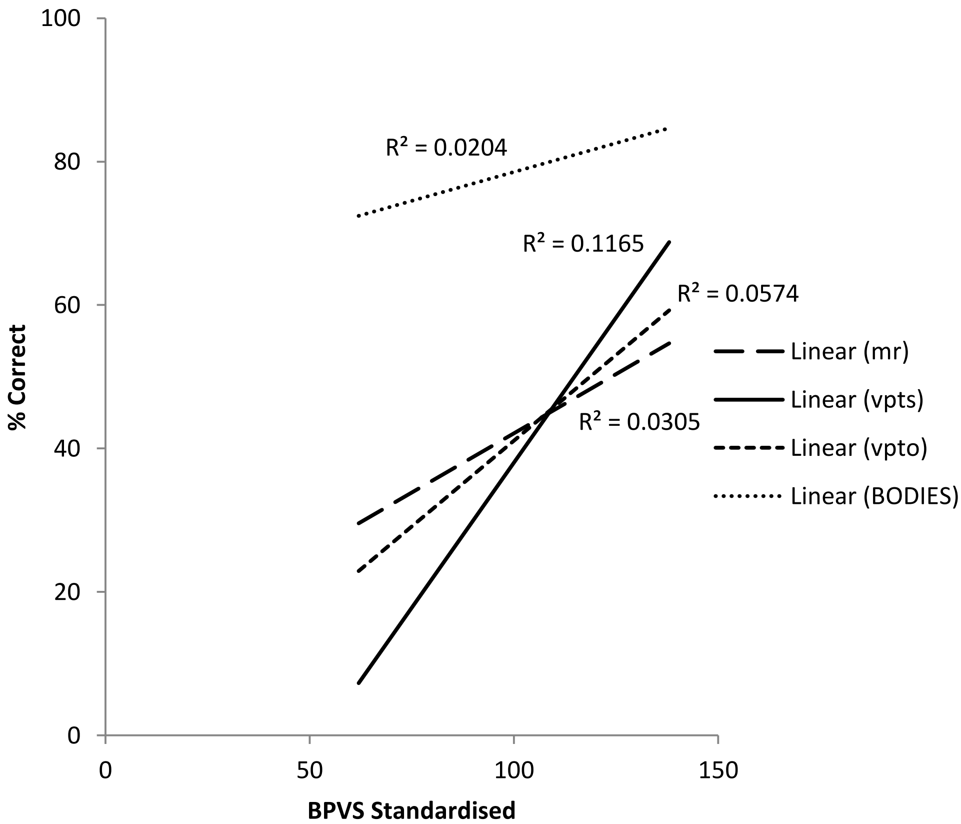

Figure 4.7 Developmental Trajectories for the development of mental rotation, VPT2S & O and Body representation across children plotted against BPVS standardised score.

4.8 Discussion

The results of experiment three showed that TD children are able to put themselves in another place in order to predict what things would look like if they were at a different point in space. They also revealed that this ability is not predicted by mental rotation performance. The results of experiment four showed that VPT2 self and other appear to be related in TD children and that general VPT2 ability is predicted by body representation. Here these results are discussed in relation to previous findings of VPT2 in TD people.

The results in this chapter showed that VPT2 S and O were highly correlated. Research has shown that whether we are asked to take someone else's point of view or transform ourselves to a different perspective, the same underlying egocentric transformation occurs (Kessler & Wang, 2012; Mazzarella, et al., 2012) suggesting that they share the same underlying processes. The results of the current study confirmed this suggestion, showing that both are predicted by body representation ability in TD children. Though studies have shown that neurally, self and other perspective taking activate different brain areas (Mazzarella, et al., 2013), behaviourally they show similar patterns between response times and angular disparity. The results in this chapter provide further behavioural evidence for VPT2 self and other being closely linked and support the notion that they are both driven by the same underlying processes.

The results of experiment three showed that VPT2 self was not predicted by mental rotation ability. These results are unsurprising, as it has been suggested that egocentric spatial transformations are the process which underlie the ability to take a different perspective (Yu & Zacks, 2010). In experiment four, further investigation into the underlying processes involved in VPT2 showed that body representation is a strong predictor of VPT2 ability. These findings support the suggestion that the ability to understand bodies from different points of view relates to the ability to take a different perspective in typically developing people. Research has shown that TD people put themselves in someone else's place by first mentally creating a motor representation of the target viewpoint and transforming themselves to match the target (Grush, 2004). Kessler and Thomson (2009) provided evidence for this process in a study which showed that manipulating the body posture of the viewer to be more or less congruent with that of the target affected time taken to transform perspectives. The evidence from this study shows that the link between body representation and VPT2 begins to develop in childhood.

In Hamilton's original study ToM ability was found to predict VPT2O performance. In the current chapter SAS was used as a proxy for ToM to examine how social skills impacts on both VPT2S and VPT2O. No relationship was found between these abilities. However, in both experiments the children generally scored similarly on the SAS with few children demonstrating evidence of poor social skills. This could go some way to explaining why no relationship was found. Further studies should look at using both ToM and measures of general social skills to examine the relationship between both of these abilities and VPT2.

Across experiments one and two different results were found in regards to which task the children showed better performance. The results of experiment three showed that the TD children performed better on the mental rotation task compared to VPT2S, whereas in experiment four, the children performed better on VPT2 S and O compared to mental rotation. Both groups of children were of a similar average age and range, as well as a similar average BPVS and range. However, the developmental trajectories between the studies are different in regards to verbal ability. Both groups of children show similar developmental trajectories for mental rotation in relation to age. However the developmental trajectory for mental rotation in relation to verbal ability is flatter in the children in experiment three (Figure 4.3), whereas in experiment four mental rotation ability increases with verbal ability (Figure 4.7). These findings suggest that differences between studies are a result of possible individual differences in regards to the development of mental rotation in the samples used. Both VPT2 and mental rotation develop steadily across childhood. The developmental trajectories for both abilities in relation to age are similar according to the data collected in this chapter. It is possible that some children may develop better mental rotation quicker whereas others will develop better VPT2 quicker. Future research could consider how individual differences contribute towards the development of these different abilities.

4.9 Broader Implications

The results of these studies provide an interesting insight into the development of VPT2 abilities in TD children. They suggest that VPT2 in TD children is highly related to the ability to represent bodies from different points of view and draw information from postures. However, so far it is unclear as to what predicts VPT2 ability in children with autism and whether it will be the same as in TD children. Chapter 5 will use the methods developed in this chapter to examine VPT2 alongside spatial transformations and body representation in children with ASD.

5 Cognitive Mechanisms underlying VPT2 in Children with Autism

The results from the previous chapter show that VPT2 in TD children is predicted by body representation performance. In this chapter, the aim is to examine VPT2 in children with autism. Whilst it is widely accepted that people with autism have difficulty understanding the beliefs and desires of others, termed Theory of Mind (ToM) or ‘mentalising’ (Baron-Cohen, 1995; Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Baron-Cohen, et al., 1985; Frith, 2001; Happe, 1995; Senju, 2012; Senju, et al., 2009), evidence as to whether VPT2 is intact or impaired is somewhat murkier. Whilst several studies discussed in the introduction to this thesis have shown that children with autism are able to take another person’s visual perspective (David, et al., 2010; Hobson, 1984; Reed & Peterson, 1990; Tan & Harris, 1991) others have found this ability to be impaired (Yirmiya, et al., 1994). This chapter aims to provide clearer evidence to whether VPT2 is impaired or intact in children with autism, and aims to investigate whether the underlying mechanisms involved in this ability are the same in ASD and TD children. Chapters 2 and 3 examined body representation and spatial transformations in children and adults with autism. Chapter 2 showed that children with autism were able to represent bodies just as accurately as TD children. Chapter 3 showed that adults with autism were impaired at egocentric transformations alongside more general perceptual differences. This chapter will examine how body representation and spatial transformations relate to VPT2 in children with ASD.

In Chapter 4 a modified version of the paradigm from Hamilton, et al. (2009) was used to examine the underlying cognitive mechanisms involved in VPT2 in TD children. In their original study, Hamilton, et al. (2009) examined VPT2 alongside mental rotation and ToM in children with and without autism. They found that the children with autism were impaired at perspective taking compared to VMA matched TD children. Though this study alone cannot provide strong evidence of impaired perspective taking in autism it provided an interesting method for investigating VPT2 alongside other cognitive processes. Hamilton et al. were successful in separating out specific difficulties with VPT2 compared to general spatial ability in ASD, showing that children with autism find VPT2 more difficult than mental rotation compared to typical children. However, there were limitations in the study that need to be addressed. Firstly there was no main effect of group, but an interaction between group and task with the ASD group performing worse on the VPT2 task and better at mental rotation compared to the TD children. Floor effects were also found for both the ASD children and the VMA matched typical children, with both groups performing at chance level on the VPT2 task. This may have masked any group differences and also means that no strong conclusions can be made as to whether the group by task interaction was being driven by impaired VPT2 in the

ASD group, or their higher mental rotation scores. This chapter will hopefully resolve some of these issues, whilst adding to our understanding of what drives VPT2 ability in autistic children. It will extend the findings of Hamilton et al (2009) in a group of more able ASD children to further examine the suggestion of VPT2 impairment compared to typically developing children. Secondly, it will explore the relationship between VPT2 and other cognitive processes in order to determine whether the ability to take someone else's perspective is predicted by the same factors in people with and without autism.

In the previous chapter the relationship between spatial ability, body representation, social skills and VPT2 was considered in TD children. It was found that body representation was predictive of VPT2 ability. This chapter will consider the contributions of body representation, spatial skills, theory of mind and other social skills to VPT2 in children with autism. It is unclear whether the processes which underlie VPT2 in TD children will be the same in children with ASD. The following paragraphs review how these different processes may contribute towards perspective taking and whether there is any evidence for them being impaired/intact in ASD.

Chapter 4 examined VPT2 self and other in TD children in order to investigate whether they were closely related and predicted by similar mechanisms. In order to transform to a different perspective a person must perform a rotation of the self (Kessler & Wang, 2012; Surtees, et al., In Press). Research has shown that participants who have particularly high autistic traits find it difficult to use the self as a reference frame for VPT2 (Brunye, et al., 2012; Kessler & Wang, 2012; Shelton, et al., 2012). These findings suggest that those with autism may find the use of their body as a reference frame in VPT2 difficult. The results from Chapter 3 support this suggestion, in which it was found that people with ASD are impaired at embodied egocentric transformations compared to TD individuals. In this chapter VPT2 self and other will be considered in people with autism. It is expected that they will be impaired at both VPT2S and O compared to TD children based on the difficulty found with completing egocentric transformations involving other people's bodies shown in Chapter 3.

Body representation was also examined in the previous chapter, specifically how it relates to VPT2. TD children were shown to be good at body representation and it related to their VPT2 ability. Being able to represent a body allows a viewer to see where another person is looking (through head orientation) and form a motor representation of their body in order to take their perspective. Previous research into body representation in people with ASD has shown mixed findings in regards to whether this ability is impaired or intact. Several studies have shown body representation to be impaired in autism (Ham, et al., 2008; Reed, et al., 2007) suggesting that they may find it difficult to represent the body from different points of view. However, other studies have shown individuals with autism to be as good at body representation as TD people (Hamilton, et al., 2007). The results of Chapter 2 showed no significant effect of group on the body representation task. However, as the ASD group were showing similar performance to younger, TD children, it is unclear whether they are truly unimpaired or whether the ability may be delayed in ASD. If children with ASD struggled to represent the body from different points of view then this could impact on their ability to put themselves in someone else's place. This chapter will examine body representation in children with autism. Expanding upon the findings of Chapter 2 in which it was shown that VMA was the strongest predictor of performance, a group of ASD children will be compared to a group of VMA matched TD children on the body representation task. Performance will also be examined in relation to VPT2 in order to investigate whether body representation predicts VPT2 in children with autism.

Mental rotation was also examined in the previous chapter, with TD showing good mental rotation ability. Hamilton, et al. (2009)'s study examined mental rotation alongside VPT2 in order to try and rule out impairment in perspective taking being related to general problems in non-social spatial ability. They found that ASD participants performed better than VMA matched TD children on the mental rotation task, which suggested that difficulties in VPT2 were not a result of more general issues with performing tasks which include spatial transformations. The results of Chapter 3 showed that though adults with autism were slower to perform mental rotation compared to TD adults, they were just as accurate. The current study will explicitly examine mental rotation performance in children with autism and whether the ability to mentally rotate a scene impacts on their VPT2 ability. Based on Hamilton's original study it is predicted children with autism will perform similarly compared to the TD children on the mental rotation task. In the previous chapter it was shown that mental rotation is not predictive of VPT2 in TD children; however this may not be the case for the ASD group in the current study. If they find egocentric transformations difficult (as suggested by results in Chapter 3) then they may attempt to use mental rotation skills in order to pass the VPT2 task by rotating the scene as opposed to themselves.

In this thesis, the idea that VPT may be important for social interaction alongside other processes such as ToM has been discussed. Research has shown a relationship between ToM and VPT2 performance in typically developing people (Farrant, et al., 2006; Hamilton, et al., 2009) which suggests that the two may be linked. However, several studies have found VPT2 to be unimpaired in people with autism even in the face of significant mentalising difficulties (David, et al., 2010; Hobson, 1984; Reed & Peterson, 1990; Tan & Harris, 1991), supporting the idea that VPT2 and ToM are dissociable. Leslie (1987) suggested that this is because VPT2 allows concrete feedback (the visual element) whereas ToM requires more abstract representations which people with ASD find difficult. Tan and Harris (1991) suggested that the relationship found between VPT2 and ToM found in TD people may not be the same in ASD. They argued that people with autism complete ToM in a different way to typical people, which may suggest that they also complete VPT2 differently. Further investigation is needed into the relationship between perspective taking and mentalising in people with ASD to assess whether ToM and VPT2 may be related. VPT2 ability has also been found to correlate with other social skills alongside mentalising (such as quality of social play, responsiveness and Autism Quotient (Baron-Cohen, Wheelwright, Skinner, et al., 2001) scores) in both typical and autistic individuals (Dawson & Fernald, 1987; Kessler & Wang, 2012; Perner, Frith, Leslie, & Leekam, 1989; Shelton, et al., 2012). This is unsurprising as those with better social skills have been found to perform better in tasks measuring social cognition (Watson, Nixon, Wilson, & Capage, 1999). In this Chapter ToM and general social ability will be examined in relation to VPT2 in the ASD children. It is expected that social skills will relate to performance in the ASD children. However as no relationship between social skills and VPT2 was found in the TD children in Chapter 4, it is expected that the same relationship will not be seen in the TD group.

Verbal ability will also be measured in this study using the BPVS. Several studies have shown that verbal ability predicts VPT2 in children with and without autism (Hobson, 1984; Tan & Harris, 1991). Here the BPVS is used as a proxy for general verbal intelligence and will be used in a regression model to examine whether age or verbal ability is a better predictor of VPT2 in children with ASD. BPVS raw scores will be used in this study as opposed to BPVS standardised as used in

Chapter 4, as the ASD and TD groups were matched on BPVS raw scores. Age will not be entered into the ANCOVA, as TD children and ASD children tend to show a different relationship between age and BPVS raw score (Thomas, et al., 2009). Whilst age and BPVS raw scores are highly correlated in TD children, children with ASD often show delayed BPVS raw scores in relation to their age. However, age will be entered into the regression models which examine the groups separately.

The current study aims to examine the processes involved in VPT2 in typical and autistic children. This study will test mental rotation, VPT2 for self, VPT2 for other, body representation, ToM, social skills and BPVS. It is expected that children with ASD will be worse at both VPT2 self and other compared to TD children. It is also predicted that this impairment will be driven by the use of difference underlying cognitive processes predicting VPT2.

5.1 Method

5.1.1 Participants

A total of 60 children from two groups participated in this study. Thirty children with a diagnosis of autism or autism spectrum disorder were recruited from schools in the Nottingham and Wales area. Their mean chronological age was 9.27 years and 27 were male (Table 5.1). The BPVS (Dunn, et al., 1997) was used to establish each child's verbal mental age, and the SCQ (Berument, et al., 1999) and the SAS (Liddle, et al., 2009) were completed by a caregiver to evaluate the child's social understanding and communication skills. All of the ASD children had a previous diagnosis from an independent clinician, confirmed by the caregiver in a background questionnaire.

The task was also completed by 30 typically developing children with a mean raw BPVS of 70.7 and a mean age of 6.83 years (Table 5.1). These children were a subset chosen from the 76 children detailed in the previous chapter. These children were matched to the ASD group on the basis of their raw BPVS score (stats can be seen in table 5.1), however an attempt was made to try and select children closest in age to the ASD group. The typically developing children were recruited during Nottingham University's Summer Scientist Week, an event designed to recruit children to take part in various studies in the form of short "games". All TD children completed the BPVS and their parent/caregiver completed the SAS. None of the typical children had a diagnosis of ASD or any other learning difficulty, confirmed by parent questionnaire.

All parents of participating children and their schools consented to taking part in the study, which was approved by The University of Nottingham ethics committee. Each child was tested individually. The ASD children were tested in a quiet room in his or her own school or home, whereas the typically developing children were tested in a quiet, partitioned cubicle in a room set up for the Summer Scientist data collection. In all, each child from both groups completed 4 tasks plus the BPVS and in the ASD group, ToM. Additionally, all children were tested on their VPT1 ability. The results of the VPT1 task are not included in this chapter; instead they will be discussed in more detail in Chapter 6. The order of all tasks was randomised across children.

Table 5.1: Participant demographics. All data are given as mean (±standard deviation) and range

	N	Age	VMA	BPVS Raw	SCQ	SAS	ToM
ASD	30	9.03±2.45 (5.18-13.63)	6.55±2.19 (4.05-13.04)	69.87±18.55 (46-119)	11.07±7.3 (0-30)	9.89±5.43 (2-27)	12±6.39 (2-33)
TD	30	6.83±1.66 (4.74-11.35)	6.68±2.12 (3.09-13.06)	70.67±18.70 (40-120)	-	24.2±4.45 (18-36)	-
t-test		t(58)=-4.65,p<0.001	t(58)=0.23, p=0.82	t(58)=0.16, p=0.87		t(56)=10.99, p<0.001	

5.1.2 Design

A repeated measures design was used to examine the effects of task on performance. Each child completed four tasks (MR, VPT2S, VPT2O and body representation) and performance on each task was measured by calculating number of trials correct, which was transformed into a percentage. Additionally, all 76 children completed a VPT1 task; however the data from that task is not discussed here, and is instead outlined in Chapter 6. Each child performed 6 trials each for the VPT2S task, VPT2O task MR task and 12 trials for the body representation task (6 meaningful and 6 meaningless). In the VPT2S, VPT2O and MR tasks the six trials presented were a selection of the four different viewpoints in a pseudo randomised order (each child was tested on one of each viewpoint and then two randomly chosen viewpoints which differed and was counterbalanced across children). For the body representation task the order of trials within a block was pseudo randomised across children and the order of blocks (meaningful and meaningless) was counterbalanced. The order in which all tasks were presented was also counterbalanced across children.

Additionally, all ASD children were tested on their ToM ability. They were assessed on their understanding of diverse desires and beliefs, knowledge access and explicit false belief, contents false belief and a penny hiding task (Baron-Cohen, et al., 1985; Devries, 1970; Wellman & Liu, 2004; Wimmer & Perner, 1983) (see Appendix Page 250). For the diverse desires task the child was shown a picture with an image of a child standing between two objects and asked which they would prefer. The child was then told which item that the child in the picture would prefer and asked which item that child would choose if offered. For the diverse belief task child was shown a sheet with a picture of a child standing between two places and asked where they thought the child's cat was hiding. They were then told where the child in the picture thought the cat was hiding and asked where that child would look for their cat. In the explicit false belief the child was shown a sheet with a picture of a child standing between two places and was told that the child thought his lost gloves were in his rucksack, but they were really in his drawers. The child was then asked where the he would look for his gloves. A second false belief task was conducted using the Sally-Anne task (described in the introduction to this thesis). A contents false belief task (the smarties task) was also used, in which the child was shown a closed smarties tube and asked what they thought was inside. It was then revealed that the tube contained a small pencil. The tube was then resealed and the child asked ‘if your friend came into the room right now, what would *they* think was inside the tube’. For the penny hiding task a game was played in which the experimenter and child took turns to hide a penny in one of their hands while the other guessed as to which hand it was in. The child was marked on their ability to hide the penny or trick the experimenter (i.e. pushing the hand without the penny in forward to make them choose the wrong hand).

For each task, each child was given a score of 1 if they passed and 0 if they failed, leading to a maximum score of 12. This score was converted into a percentage correct for analysis. TD children were not tested for their ToM ability due to time constraints in summer scientist data collection.

5.1.3 Materials

The materials for the VPT2S and MR tasks were a small turntable, an opaque pot and three toys. The turntable had a coloured strip running along each side to form a square in which to place the toy (See Figure 5.1). There were three toys used in this study, a bear, a frog and a small fire truck.

For the body representation task, the body stimuli from Chapter 2 were used. Only bodies were included in this study; hands and objects were not included. There were two sets of stimuli, a set of meaningful (MF) body postures and a set of meaningless (ML) body postures. For each trial there were two cards, one depicting two body postures (one target match and one foil) and one depicting an exemplar to be matched (Figure 4.2)

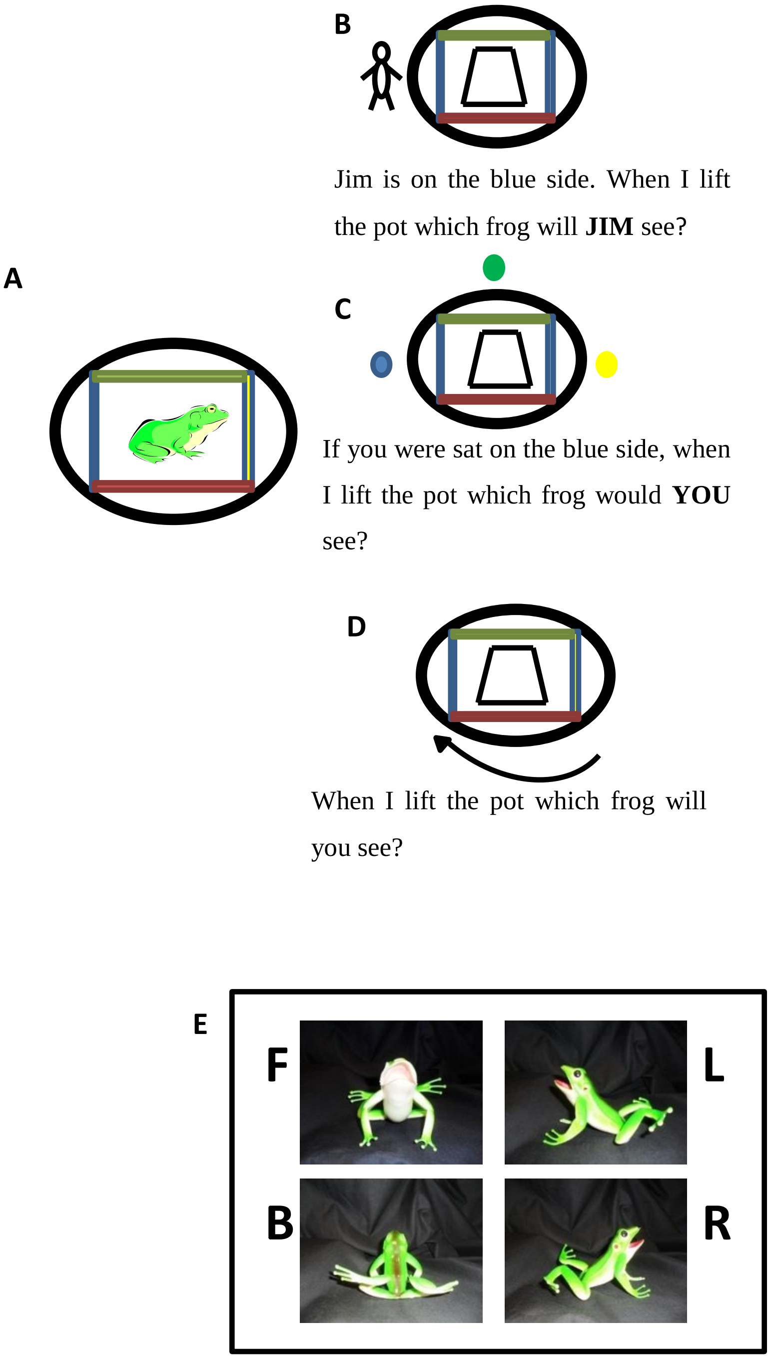

Figure 5.1 Examples of stimuli and tasks. **A** depicts the toy place on the turntable. The toy is then covered. **B** depicts VPT2O: What will JIM see? **C** depicts VPT2S: What will YOU see? **D** depicts the mental rotation task, in which the toy is rotated and the child is asked which view they will see when the pot is lifted. **E** displays an example of a response card given to the child.

5.1.4 Procedure

There were two VPT2 tasks and one MR task. For the VPT2S (Figure 5.1c) the toy was placed upon the turntable facing one of the coloured strips. The child was presented with a picture card bearing four images of the toy from different viewpoints. At the start of each trial, the child was asked ‘which picture can you see?’(Figure 5.1a). This established the initial orientation of the toy and that the child was attending to the toy. The toy was then covered with an opaque pot and the child asked ‘if you were sitting at the [blue] side of the table (there were also coloured stickers on the appropriate table sides), which picture would you see when I lift up the pot?’ (Fig 5.1c) Other colours were substituted as appropriate, to test all 4 viewpoints. For the VPT2O task, the first part of the trial was identical to the VPT2S trial in that the child was presented with the toy on the turntable and asked to establish its initial orientation. The toy was then covered with the opaque pot. Once the toy was covered, a doll was placed at another side of the table, and the child was asked, ‘Jim is sitting on the [blue] side of the table, when I lift the pot up which picture will Jim see?’(Fig 5.1b).

For the MR task, a toy was placed upon the small turntable facing one of the coloured strips. At the start of each trial the child was asked ‘which picture can you see’ to establish the initial orientation of the toy and that the child was attending to the toy. The toy was then covered with an opaque pot, and rotated to a different orientation. The child was then asked ‘when I lift the pot up, which picture will you see?’ (Fig 5.1d).

For the body representation task, the child sat at a desk next to the experimenter. On each trial, the child was given a laminated card with two pictures (the target and foil) and told “here are two pictures”. Then the experimenter gave the child a second laminated card with a single picture (the exemplar) and said “Here is another picture, which one of these (point to double picture card) matches your picture?” The child could respond verbally, or by pointing or putting the single card with the appropriate match. The first trial was given as a practice trial, and any errors the child made were corrected with an explanation. After the child understood the task, the experimenter presented the 12 experimental trials, 6 meaningful bodies, and 6 meaningless bodies. Praise was given throughout regardless of response.

5.2 Results

5.2.1 Replicating Hamilton's Analysis

The original study from Hamilton et al. (2009) compared mental rotation and VPT2 other. To examine whether results from this study replicated results found in Hamilton et al. 2009 an ANCOVA was used to examine performance on MR and VPT2O in the autism group and typical group. Each child's score out of 6 on the MR task and VPTO task was entered as repeated measures factors, with group, BPVS-raw score and SAS score as additional predictors. Results showed no effect of task (F (1, 54) =2.795, p=0.100) and no interaction between task and BPVS (p=0163). There was a significant interaction between task and group (F (1, 57) =5.924, p=0.018), with the typical children scoring worse on mental rotation compared to the ASD group (t (58) =-2.11, p=.039), but showing similar performance on the VPT2 other task (t (58) =-.349, p=.728). This replicates the result of Hamilton et al, 2009.

There was no significant effect of SAS (p=0.280) however there was a marginal interaction between task and SAS (F (1, 54) =3.042, P=0.087). There was a significant effect of BPVS, with higher BPVS children scoring better (F (1, 54) =36.879, p<0.001) and a marginal main effect of group (F (1, 54) = 3.366, p=0.066).

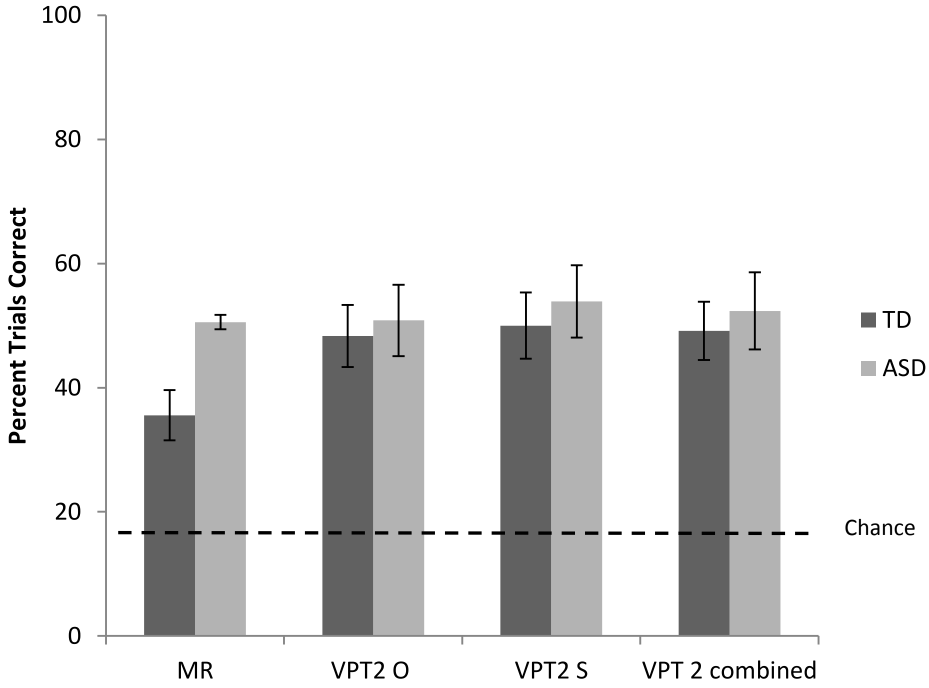

Figure 5.2 Mean scores (±standard error) for the TD and ASD children across the VPT and MR tasks. Each child completed 6 trials so the maximum score for each task was 6 and chance 1.5 (25%). Results are displayed here as a percentage with errors bars to show S.E.

5.2.2 Specific Processes Underlying VPT2S and VPT2O in ASD

In order to analyse whether there were any differences between the variables that predicted VPT2S and O in the current study, regression analyses were conducted on VPT2S and VPT2O. Data for the 30 TD children who completed the experiment were entered into a multiple linear regression model to determine which factors out of mental rotation, posture representation, SAS, BPVS and age predicted VPT2S ability. The regression model had an overall model fit of R^2=.50. Results showed that in the typical group, performance on VPT2 was significantly predicted by performance on BPVS (β=.483, p=0.03) and marginally predicted by posture representation (β=.346, p=.092). There were no significant effects of age (p=0.32), SAS score (p=0.63) or MR score (p=0.16).

The same data were entered as predictors for VPT2O in the 30 TD children. The regression model had an overall model fit of R^2=.68. Results showed that in the typical group, performance on VPT2 was significantly predicted by performance on posture representation (β=.488, p=.005). There were no significant effects of age (p=0.14), BPVS (p=0.23), SAS (p=0.88) or MR (p=0.46).

Data for the 30 ASD children who completed the experiment was also entered into a multiple linear regression model to determine which factors out of mental rotation, posture representation, SAS, BPVS and age predicted VPT2S ability. The regression model had an overall model fit of R^2=.60. Results showed that in the autism group performance on VPT2 was significantly predicted by performance on mental rotation (β=.584, p<.003) and marginally by performance on the BPVS (β=.357, p=.067). There were no significant effects of age (p=0.47), SAS score (p=0.89), or posture performance (p=0.22).

The same data were entered as predictors for VPT2O in the 30 ASD children. The regression model had an overall model fit of R^2=.72. Results showed that in the autism group performance on VPT2 was significantly predicted by performance on BPVS (β=.419, p=.012), age (β=-.306, p=.023) and mental rotation (β=.585, p<.001). There were no significant effects of SAS score ($p=0.23$) or posture performance ($p=0.84$).

Additionally, a regression analysis on the ASD group (N=30) was also conducted to include the variables collected only in the ASD group. Here ToM and SCQ were entered alongside mental rotation, posture representation, SAS, BPVS and age as predictors of VPT2S. The regression model had an overall model fit of $R^2=.69$. Results showed that in the autism group performance on VPT2 was significantly predicted by performance on the SCQ ($\beta=-.424$, $p=.029$) and mental rotation ($\beta=.501$, $p=.007$). There were no significant effects of age ($p=0.29$), BPVS ($p=0.18$), SAS ($p=0.28$), ToM score ($p=0.18$) or posture performance ($p=0.44$).

The same data were entered as predictors for VPT2O in the 30 ASD children. The regression model had an overall model fit of $R^2=.74$. Results showed that in the autism group performance on VPT2 was significantly predicted by performance on BPVS ($\beta=.414$, $p=.022$), age ($\beta=-.297$, $p=0.032$) and mental rotation ($\beta=.567$, $p<.001$). There were no significant effects of SCQ score ($p=0.30$), SAS score ($p=0.19$), ToM score ($p=0.98$) or posture performance ($p=0.85$).

5.2.3 VPT2 and Mental Rotation in Autism

The current study included VPT2 self and other as two separate tasks. However, Chapter 4 demonstrated these processes to be highly correlated. In order to examine whether VPT2S and VPT2O were significantly different processes in the matched groups, an ANCOVA was conducted with VPT2S & O as repeated measures factors group as a between groups variable and BPVS raw score and SAS entered as covariates. The ANCOVA showed that there was no significant effect of task ($p=.496$) and no interaction between task and group ($p=.684$), suggesting that VPT2 self and VPT2 other are very similar in both ASD and TD participants. To further investigate this further a bivariate correlation was performed, with VPT2 O and VPT2 S as inputs. This showed that VPT2 S and O were highly correlated across children ($r=.65$, $p<0.001$). As both tasks showed similar performance, VPT2S and VPT2O were averaged together to give a single VPT2 score for each child. This was used in further analysis.

The effect of task (VPT2 and mental rotation) was analysed in the matched groups. An ANCOVA with a between groups variable of group, and covariates of BPVS raw score and SAS compared performance on the mental rotation and VPT2 tasks. Results showed a significant effect of task ($F (1, 54) =5.330$, $p=0.025$) with both groups more accurate on the VPT2 task than mental rotation. There was a significant effect of BPVS raw score ($F (1, 57) =40.998$, $p<0.001$) with higher BPVS participants showing more accuracy. There was no interaction between task and BPVS ($F(1, 54) = 2.592$, $p = 0.113$). There was a significant effect of group ($F(1, 54) = 4.551$, $p = 0.037$) with the ASD group performing slightly better. There was a significant interaction between task and group ($F(1, 54) = 6.576$, $p = 0.013$) with the typical group showing poorer performance on the MR than the AS group ($t(58) = -2.11$, $p = .032$), but no difference between groups in regards to performance on the VPT2 task ($t(58) = -.431$, $p = .668$). There was no significant effect of SAS ($p = .204$), however, there was a marginally significant interaction between task and SAS ($F(1, 54) = 3.214$, $p = 0.079$).

5.2.4 Body Representation

An ANCOVA was used to examine the effects of group and stimulus (MF/ML) category on accuracy, with raw BPVS entered as a covariate. There was a significant effect of meaning ($F(1, 57) = 10.37$, $p = .002$) with both groups showing higher accuracy for the meaningless stimuli. There was a significant effect of group ($F(1, 57) = 5.68$, $p = .021$) with the ASD group performing worse than the TD group and a significant effect of raw BPVS ($F(1, 57) = 15.99$, $p < .001$) with higher BPVS participants performing better. There were no significant interactions between meaning and BPVS ($p = 0.44$) or meaning and group ($p = 0.56$).

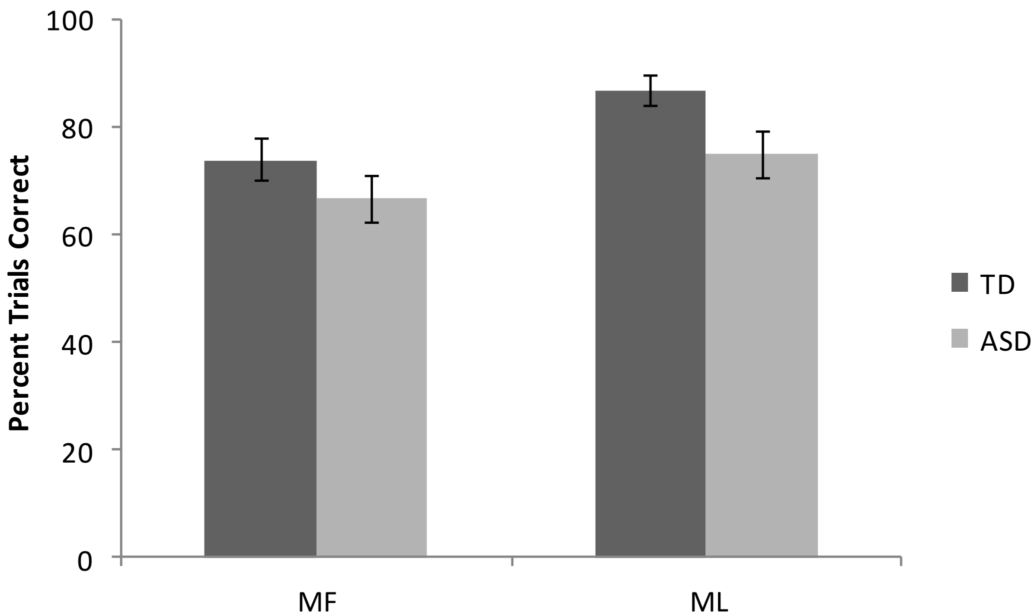

Figure 5.3 Mean scores (±standard error) for the TD and ASD children in the MF and ML tasks. Each child completed 6 trials so the maximum score for each task was 6 and chance 1.5 (25%). Results are displayed here as a percentage with errors bars to show S.E.

5.2.5 What Predicts VPT2 in children with Autism

Regression analyses were used to test which measures predicted VPT2 performance in the typical and ASD children. Enter method was used for all regression analyses detailed in this chapter. Data for 30 TD children was entered into a regression model (N=30) with mental rotation, posture representation, SAS, BPVS and age as entered as predictors of VPT2. The regression model had an overall fit of R^2=.65.

Results showed that performance on VPT2 was significantly predicted by performance on BPVS (β=.385, p=.038) and posture representation (β=.458, p=.011). There was no significant effect of age (p=0.92), SAS score (p=0.68) or MR (p=0.56).

Data for the 30 ASD children was also entered into a multiple linear regression model to determine which factors out of mental rotation, posture representation, SAS, BPVS and age predicted VPT2 ability. The regression model had an overall fit of R^2=.73. Results showed that in the autism group performance on VPT2 was significantly predicted by performance on BPVS (β=.473, p=.012) and mental rotation (β=.661, p<.001). There was no significant effect of age (p=0.37), SAS score (p=0.44) or posture representation (P=0.49).

Additionally, a regression analysis on the ASD group (N=30) was also conducted to include the variables collected only in this population. Here ToM and SCQ were entered alongside mental rotation, posture representation, SAS, BPVS and age as predictors. The regression model had an overall fit of R^2=.78. Results showed that in the autism group performance on VPT2 was significantly predicted by performance on BPVS (β=.392, p=.043), mental rotation (β=.597, p<.001) and SCQ (β=-.311, p=.048). There were no significant effects from age (p=0.47), SAS score (p=0.59), posture performance (p=0.71) or ToM score (p=0.41).

5.3 Discussion

In this study 30 children with autism and 30 TD children were tested on their ability to perform VPT2. Results showed that children with autism were impaired at VPT2 compared to the TD children, replicating the findings of Hamilton, et al. (2009). Importantly there were no floor effects in the VPT2 task as reported in Hamilton’s study due to the use of a more able ASD group. The current study also showed that VPT2 is predicted by different abilities in TD and autistic children. To summarise these results, figure 5.4 displays performance sketched in relation to age in both groups of children. The children with ASD had a mean age of around 9 years, whereas the TD children had a mean age of around 7 years. Both groups had a VMA of around 7 years, as measured by the BPVS. For the VPT2 task, both groups of children showed performance at the level expected for 7 year olds, which is consistent with CA in the TD children but lower than CA in the ASD children. In the mental rotation task, the TD children performed at the level expected for 7 year olds, whereas the ASD children performed at the level expected for 9 year olds, suggesting mental rotation is intact in autism and performance is age appropriate. In the body representation task, the TD children performed at the level expected for 7 year olds, whereas the ASD children performed at what might be expected from children of around 5 years of age, suggesting that the ability to represent bodies in this group was impaired. Whereas TD children appear to be more reliant on information gained from body representation to complete VPT2 (maintaining findings from the previous chapter), the ASD children were more reliant on their ability to mentally rotate objects. This use of a different strategy to complete VPT2 in autism may explain why some studies have shown VPT2 in autism to be impaired whereas others have found it to be intact (Hamilton, 2008; Hobson, 1984; Tan & Harris, 1991). It has been suggested that some VPT2 tasks may be easier for people with ASD than others (Langdon & Coltheart, 2001), as they may favour the use of spatial cues where available. The results of the current study support the idea that people with autism will use spatial information in social tasks if it is available to them. Here I discuss the findings of this study and how performance in VPT2 relates to each of the different cognitive processes that were measured.

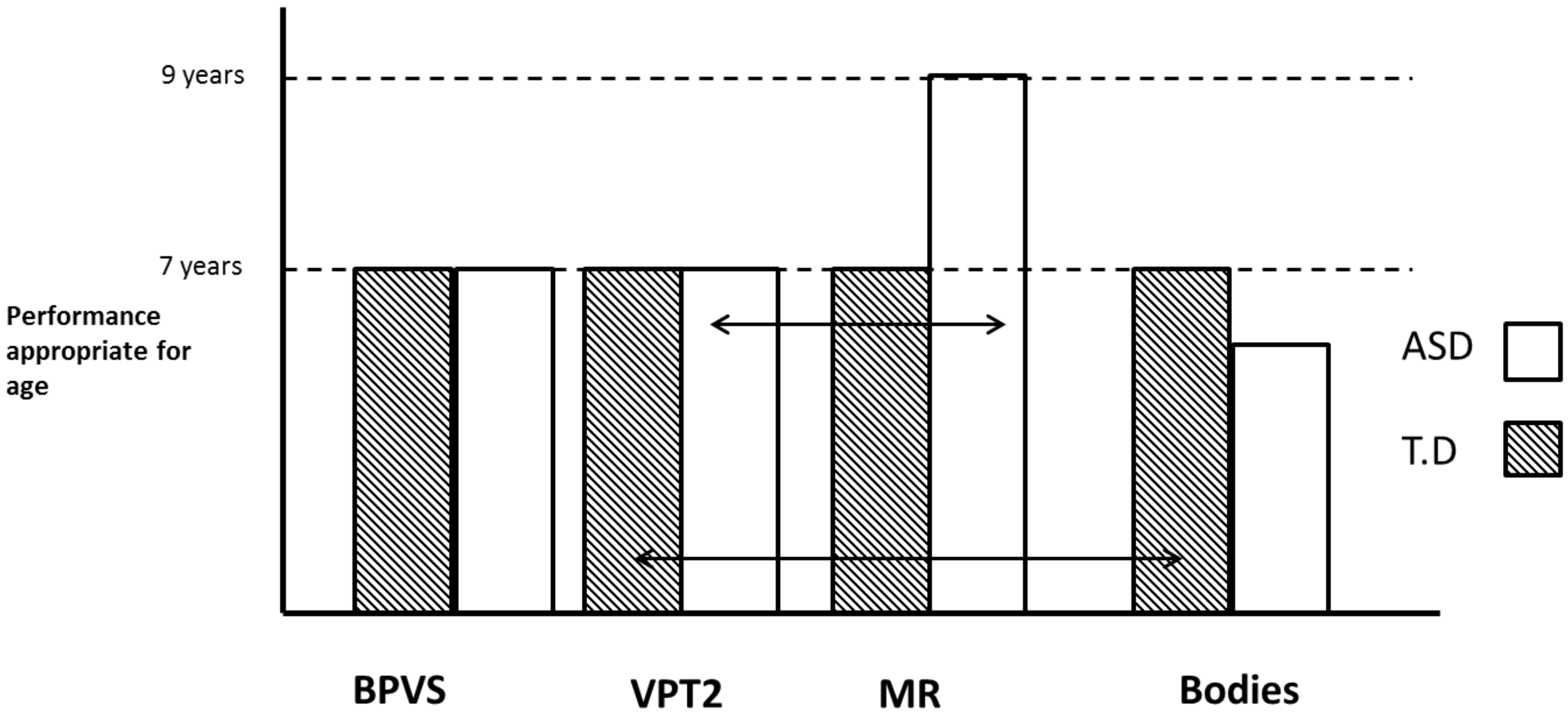

Figure 5.4 This sketch displays the expected age appropriate performance across different domains in the typical and autistic children. Whilst the TD children are performing at the level appropriate for their chronological age across domains, the children with ASD are only performing at the expected level in the mental rotation task. Their performance on the VPT2 task is in line with their VMA, whilst performance on the bodies task is lower than expected for both chronological age and VMA. The arrows denote the results of the regression in both groups, showing a significant relationship between bodies and VPT2 in the TD group, and MR and VPT2 in the ASD group.

Bodies

The results of this study showed that the autistic children were impaired on the body representation task compared to the typical children. These findings suggest that children with autism may find it difficult to represent bodies from different points of view. Several studies have shown children with autism to be impaired on posture matching tasks (Ham, et al., 2008; Reed, et al., 2007), however the results from Chapter 2 suggested that children with ASD may be unimpaired at body representation compared to both typical children and those with learning difficulties. The method used to examine the groups (using a developmental trajectory method instead of matched groups) in Chapter 2 made it difficult to make a strong conclusion as to whether body representation was intact in autism as they differed strongly from the comparison groups in regards to age and VMA. The same stimuli and procedure were used in the current study with a group of ASD children and VMA matched TD children and evidence of impairment was shown. It is clear from these results that more research is needed into this area in order to form a clearer picture of body posture representation in autism across a broader range of ages and abilities. However, results appear to suggest that children with autism may struggle to use information from bodies in the same way as TD children.

Mental Rotation

Results from the mental rotation task showed that the typically developing children performed significantly worse than the ASD children. This can perhaps be best understood in terms of developmental change. Both the typically developing and ASD children showed age appropriate performance on the mental rotation task (Fig 5.4). As the typical group was performing at the level expected from typical 7 year olds and the ASD group performing at the level expected for typical 9 year olds, there was a significant difference in performance. The children with autism were performing above the level predicted by their VMA, which was also found in the original study by Hamilton et al (2009). This is unsurprising as research has shown that people with autism often display better performance on non-verbal measures of performance compared to their verbal ability (Joseph, Tager-Flusberg, & Lord, 2002). If we had compared a group of typical 9 year olds and 9 year olds with autism we would not expect to find this difference. Thus, the ability to do mental rotation is not *superior* in people with autism as such, but simply age appropriate compared to performance in other domains such as verbal ability or body representation.

Additionally, results showed that VPT2 performance was strongly predicted by mental rotation ability in the ASD children. These results suggest that children with autism may not be using a standard perspective transformation strategy to complete VPT2. Whilst TD children rely on their ability to perform an embodied transformation, the children with autism may be instead relying on the ability to rotate a scene or the objects within it. Previous research has suggested that people with autism may draw upon spatial information in social tasks if it is available to them (Langdon & Coltheart, 2001). The results in the current study suggest that in tasks which include both a spatial and social element, people with ASD can pass them if they have good spatial abilities. However, it can be seen that the use of spatial skills only do not lead to highly accurate performance.

ToM/Social Skills

The results did not find a relationship between ToM and VPT2 in the children with autism (ToM was not measured in the typical children). Previous research has suggested that VPT2 and ToM are closely related in typical children (Farrant, et al., 2006; Hamilton, et al., 2009), developing at around the same time (Flavell, 1988) and may be driven by similar underlying cognitive processes (Aichhorn, et al., 2006). However, it has been proposed that this relationship may not hold true for children with ASD. Tan and Harris (1991) suggested that children with autism may use a different strategy to typically developing children in order to pass ToM tasks. Hamilton found that VPT2 and ToM were closely related in TD children. However, in the current study it was shown that VPT2 is indeed predicted by different processes in TD people and in people with autism. Thus it is entirely possible that ToM may also be predicted by different underlying cognitive processes in people with

ASD. This may help explain why these abilities are not found to correlate in people with autism. Currently it is difficult to speculate which processes may be involved in ToM in ASD and how these may differ from those used in VPT2. Further research is needed in order to examine more closely the relationship between VPT2 and ToM and their underlying cognitive mechanisms in both typical and autistic individuals.

There was a relationship between SCQ score and VPT2 ability in the ASD children, with participants who scored lower on the SCQ being better at VPT2. These results suggest that children with ASD who have better social skills are better at perspective taking. This is consistent with similar findings from previous studies which have explored the link between VPT2 and social skills in autism (Dawson & Fernald, 1987). These findings are coherent with the idea that VPT2 is a sociocognitive ability and aids social interaction by allowing people to put themselves in someone else’s place.

5.4 Broader Implications

The results of this study show that people with autism are impaired at Level 2 visual perspective taking. This impairment appears to be driven by the use of a different strategy to TD children: the children with autism are relying on mental rotation ability whereas the TD children are using body representation skills. The findings of this study provide some explanation as to why studies of VPT2 in autism so far have had inconsistent findings and provide further motivation for examining the underlying processes involved in perspective taking in autism. They also suggest that it may be interesting to examine the link between VPT2 and ToM in autism, as the findings in this chapter suggest that the two are unrelated in ASD.

6 Level 1 VPT in Children with Autism

In the previous chapter, the ability to perform VPT level 2 was examined in children with autism. The results showed that VPT2 was impaired in ASD. This chapter will focus on Level 1 VPT in autism, asking whether this ability may also be impaired.

Level one VPT (VPT1) is defined as ability to know whether or not a person can see an object (i.e. it is occluded from their line of sight). It develops relatively early in typically developing (TD) children at around 18-24 months (Moll & Tomasello, 2004; Moll & Tomasello, 2006). In the introduction to this thesis, it was shown that studies of VPT1 in autism have been inconsistent as to whether this ability is impaired or intact (Hobson, 1984; Leekam, et al., 1997; Warreyn, et al., 2005). Whilst the majority of evidence points to intact VPT1 in autism (Baron-Cohen, 1989; Hobson, 1984; Reed, 2002; Reed & Peterson, 1990), there have been studies showing the ability to be impaired (Leekam, et al., 1997; Warreyn, et al., 2005). This chapter focuses on VPT1 in ASD, asking is VPT1 impaired compared to typically developing children.

The development of VPT1 in TD children marks the shift away from a purely egocentric viewpoint of the world. It is the point at which children begin to notice that people have different points of view to themselves (Flavell, 1977), for example being aware that an adult may not see a toy which is hidden behind a box. In order to perform VPT1 a child must be able to form representations between themselves, other people and objects. Dyadic representations code the relationship between another person and an object (i.e. Jim can see the teddy). They can be formed without having to take the self into account. Dyadic representations are important for VPT1 as they allow a child to form a relationship between what other can people can and can't see. It has been argued that dyadic representations are intact in autism (Leekam, et al., 1997) and that autistic children are able to encode the relationship between and object and themselves or an object and another person. Thus, this would suggest that children with autism should be able to perform VPT1. Triadic representations are representations between the self, another person and an object (I can see the teddy and Jim cannot). Triadic representations are essential for joint attention (JA), an ability which has been implicated in perspective taking. Joint attention is the ability to form a triadic representation between the self, an item and another person (i.e. a child making eye contact with an adult and then pointing to a toy). Research has shown that JA in autism appears to be impaired due to difficulty forming triadic representations (Warreyn, et al., 2005). Children should be able to complete VPT1 with having to use triadic representations, however if a task has triadic demands, children with autism may struggle.

Eye gaze following has also been shown to be important for VPT1 (Warreyn, et al., 2005). Eye gaze can be split further into two separate abilities: The first is the simple detection of another person's gaze, termed eye direction detection (EDD) (Baron-Cohen, 1997). This is the ability to detect where another person is looking and is based upon dyadic representations (Jim sees the teddy). EDD has been shown to be intact in autism (Warreyn, et al., 2005). The second ability involved in eye gaze following is gaze monitoring (GMT). This is the ability to respond spontaneously to changes in a person's eye or head position, following their gaze from place to place. GMT appears to be impaired in autism (Leekam, et al., 1997) despite the ability to perform basic gaze detection. Thus, it is worth considering which skills are needed to perform VPT. VPT2 clearly demands triadic representations (I can see the front of the teddy and Jim can see the back); hence why people with autism may find VPT2 difficult. However, it should be possible to complete VPT1 using EDD and dyadic representations only (I see the teddy OR Jim sees the teddy). In the introduction to this thesis several studies examining VPT1 were discussed, here these studies are revisited to examine evidence of VPT1 impairment in autism.

VPT1 has been measured in TD children using a variety of tasks, most of which use item visibility questions (Masangkay, et al., 1974; Moll, et al., 2007; Moll & Tomasello, 2004; Moll & Tomasello, 2006). The child is presented with an item which is either visible or occluded from the view of another person and has to respond to whether the person can see the item (Moll & Tomasello, 2004). Studies of VPT1 using item visibility in autism have shown this ability to be intact.

Hobson (1984) examined VPT1 in adolescents with autism and verbal mental age (VMA) matched TD children using a ‘hide and seek’ game paradigm in which participants were presented with a display which included hiding holes and two figures. The participant had to ‘hide’ their figure from the other, indicating in which hole the figure would need to be placed so that they would not be seen. The participants with autism performed similarly to the ability matched typically developing children. Hobson also found that verbal ability was a significant predictor of performance, with higher VMA children performing better. These results have since been replicated using similar paradigms (Reed, 2002; Reed & Peterson, 1990; Tan & Harris, 1991). The findings from these studies suggest that children with ASD are able to understand the concept of ‘hiding’ and what other people can see.

VPT1 has also been examined using line of sight paradigms. Leslie and Frith (1988) used a line of sight paradigm to investigate VPT1 in children with autism. All of the autistic children were able to complete the task, suggesting that they had a basic understanding of what the doll could and could not see.

Baron-Cohen (1989) used a line of sight paradigm to examine VPT in children with autism and a group of TD children. Children were presented with a task in which an experimenter would orient their gaze or body towards one of six items surrounding the child and the child would have to identify which item they were looking to. The results showed no significant differences in performance between the ASD and

TD groups. Baron-Cohen's study has been replicated since, though findings have been mixed. Leekam, et al. (1997) examined VPT1 alongside GMT in children with ASD and found that they performed worse on both tasks compared to TD controls. The TD group performed at ceiling (100% correct) whereas the mean for the ASD group was only 66%. They also found VMA to be a significant predictor of performance, with the less than half of the lower VMA children in the ASD group passing the task.

Warreyn, et al. (2005) examined VPT1 using a similar paradigm to Baron-Cohen (1989), however they tested younger children than examined in previous studies. They found that 3-7 year old with ASD were impaired at both a joint attention task and VPT1 compared to a group of age matched TD controls. The authors suggested that children with autism may develop VPT1 skills slower than TD children. Similarly to Hobson (1984) and Leekam et al. (1997), they found that VPT1 ability correlated positively with VMA in the ASD children. In the previous studies older ASD children were compared to younger, VMA matched TD children. Findings suggest that whilst children with autism show performance in line with what would be predicted for their VMA, performance is delayed in regards to CA. Results from Warryen's study suggest that VPT1 may be delayed in children with ASD in relation to their chronological age. Interestingly, in the two studies that did find poorer performance in the autism group, the possibility of using triadic representations was possible in the task. As some items were placed behind the children they could take into account the relationship between themselves, the object and the experimenter instead of the experimenter and the object only.

The current study aimed to examine VPT1 ability in children with autism compared to TD children in order to gain further insight as to whether this ability is impaired or intact in ASD. The task uses a repeated measures design in which children have to decide whether they themselves, or the person sat opposite would see a sticker placed on the side of a toy. It is designed to draw on dyadic representations (Jim can see the sticker *or* I can see the sticker). If children with ASD are unimpaired at VPT1 then we would expect to see similar performance to the TD children on this task.

6.1 Method

6.1.1 Participants

A total of 60 children from two groups participated in this study (Table 6.1). Thirty children with a diagnosis of autism or autism spectrum disorder were recruited from schools in the Nottingham and Wales area. Their mean chronological age was 9.27 years and 27 were male (Table 6.1). The BPVS (Dunn, et al., 1997) was used to establish each child's verbal mental age, and the SSQ (Berument, et al., 1999) and the SAS (Liddle, et al., 2009) were completed by a caregiver to evaluate the child's social understanding and communication skills. All of the ASD children had a previous diagnosis from an independent clinician, confirmed by the caregiver in a background questionnaire.

The task was also completed by 30 typically developing children (mean chronological age: 6.16). The typically developing children were recruited during Nottingham University's Summer Scientist Week, an event designed to recruit children to take part in various studies in the form of short "games". All TD children completed the BPVS and their parent/caregiver completed the SAS instead of the SCQ as it is a more appropriate measure of social ability in non-clinical children. None of the typical children had a diagnosis of ASD or any other learning difficulty, confirmed by parent questionnaire. The ASD and TD children were matched using their raw BPVS scores. All parents of participating children and their schools consented to taking part in the study, which was approved by The University of Nottingham ethics committee. Each child was tested individually. The ASD children were tested in a quiet room in his or her own school or home, whereas the typically developing children were tested in a quiet, partitioned cubicle in a room set up for the Summer Scientist data collection.

Table 6.1: Participant demographics. All data are given as mean ±standard deviation and (range)

	N	Age	VMA	BPVS Raw	SCQ	SAS	ToM
ASD	30	9.03±2.45 (5.18-13.63)	6.55±2.19 (4.05-13.04)	69.87±18.55 (46-119)	11.07±7.3 (0-30)	9.89±5.43 (2-27)	12±6.39 (2-33)
TD	30	6.83±1.66 (4.74-11.35)	6.68±2.12 (3.09-13.06)	70.67±18.70 (40-120)	-	24.2±4.45 (18-36)	-
t-test		t(58)=-4.65,p<0.001	t(58)=0.23, p=0.82	t(58)=0.16, p=0.87		t(56)=10.99, p<0.001	

6.1.2 Design

Each child completed three tasks (control, VPT1 self (VPT1S) and VPT1 other (VPT1O)) with 2 trials per task. There was one 'yes' and one 'no' answer in each pair. The order of the questions within a pair of trials and the order of the three types of trial were counterbalanced across children. Additionally, each child also completed tasks to measure VPT2, body representation and mental rotation (these are described in Chapters 4 and 5). Task order was randomised across children. All ASD children were also tested on their ToM ability. They were assessed on their understanding of diverse desires and beliefs, knowledge access, explicit and implicit false belief, contents false belief and a penny hiding task (Baron-Cohen, et al., 1985; Devries, 1970; Wellman & Liu, 2004; Wimmer & Perner, 1983). For each task, each child was given a score of 1 if they passed and 0 if they failed, leading to a maximum score of 12. This score was transformed into a percentage for use in analysis. TD children were not tested for their ToM ability due to time constraints.

6.1.3 Materials

The materials for the VPT1 task were a small turntable, an opaque pot and three toys. The turntable had a coloured strip running along each side to form a square in which to place the toy (Figure 6.1). There were three toys used in this study, a bear, a frog and a small fire truck.

6.1.4 Procedure

For the VPT1 task, a toy with a sticker on one side was placed on the turntable. The sticker facing could be on the side facing the child or on the side facing away from the child. The child was asked ‘Can you see the sticker’ to establish attention. The toy was then covered with a pot. As a control question, the child was asked ‘When I lift the pot up, will you see the sticker?’ For VPT1O trials a doll was placed opposite the child and the child was asked ‘When I lift the pot up, will Jim see the sticker?’ For VPT1S trials, the child was asked ‘If you were sat at the (colour) side of the table, would you see the sticker?’ Each child completed two VPT1 control trials, two VPT1O trials and two VPT1S trials, with one ‘yes’ and one ‘no’ answer in each pair. The order of the questions within a pair of trials and the order of the three types of trial were counterbalanced across children.

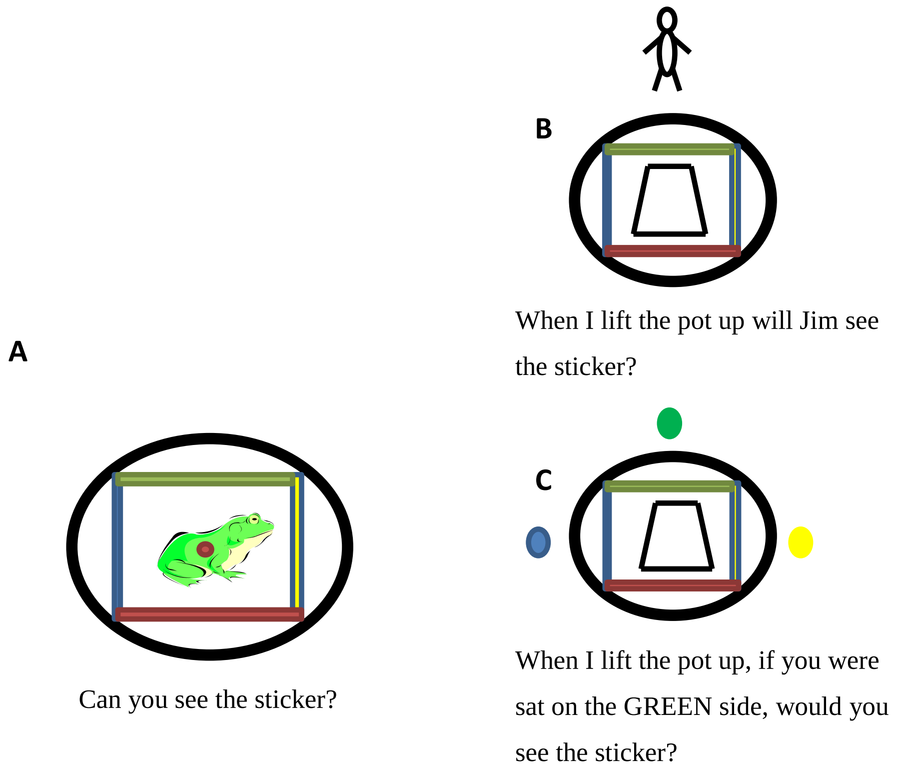

Figure 6.1 Stimuli and tasks **A.** The toy was placed on the turntable facing one of the coloured strips and the child asked if they could see the sticker. **B.** In the VPT1O trials the toy was covered, and the child asked if Jim would see the sticker when the pot was lifted **C.** In the VPTS trials the toy was covered and the child asked if they would see the sticker if sitting at another position at the table.

6.2 Results

6.2.1 VPT1 in Autism

VPT1 was tested with 3 tasks (control/self /other) and scores for all three were summed to give a score out of 6. This score was then transformed into a percentage. Children in the TD group performed at ceiling (mean =99) but surprisingly, the children with autism made errors even in this very simple task (mean =77). A one way ANOVA with factors of task, group and BPVS raw score showed that there was a significant effect of group on task ($F(1, 57)=23.02$, $p<0.001$) with the typical group scoring better than the autism group. There was also a significant effect of BPVS ($F(1, 57)=7.580$, $p=0.008$) with higher BPVS participants being more accurate. As can be seen from Figure 6.2, there was a ceiling effect in the TD group, whereas the ASD group showed much more variability in performance.

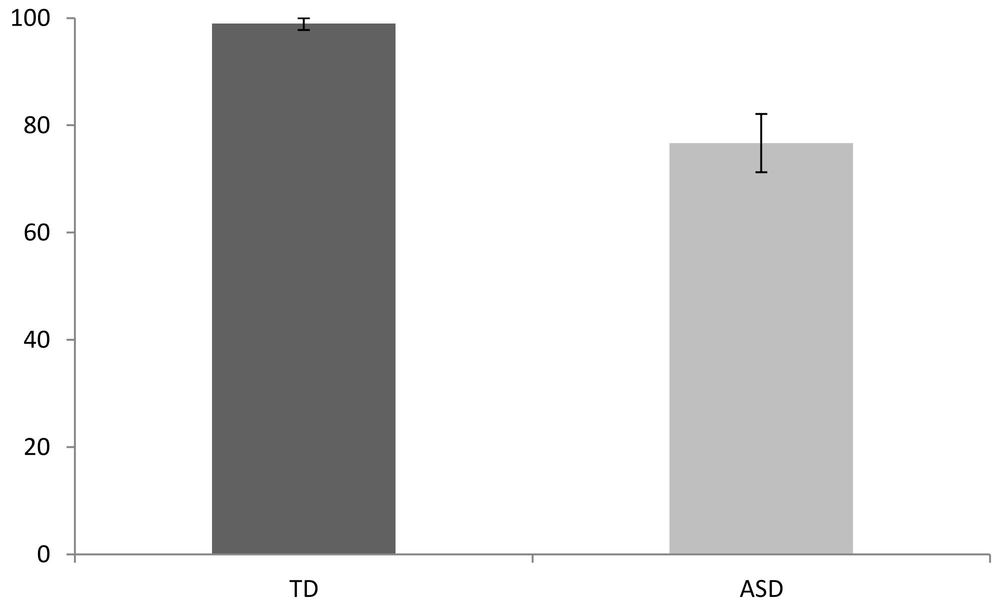

Figure 6.2 Mean scores for the TD and ASD children on the VPT1 task (±standard error) are displayed. Each child performed 6 trials so the maximum score is 6 and chance is 1.5. Results are displayed here as a percentage with error bars to show S.E.

6.3 Discussion

Results from this study show that children with ASD are impaired at performing VPT1 compared to TD children. While the TD group performed at ceiling level on the task, the ASD group's performance was much lower. These results suggest that children with autism may have difficulty at the most basic level of perspective taking. Here the possible reasons for impaired performance in the ASD group and how these results relate to previous studies of VPT1 in autism are discussed.

The TD children in this study performed at ceiling level, which is consistent with previous studies of VPT1 in typical children of this age (VMA above 6 years old). As VPT1 develops early in TD children, we would expect that by 6 years old they would be adept at tasks which involve this ability. The ASD children however, performed much lower than would be expected based on the findings of previous studies (Baron-Cohen, 1989; Hobson, 1984; Reed, 2002; Reed & Peterson, 1990). These studies demonstrated that children with ASD were unimpaired on a variety of VPT1 tasks using a line of sight paradigm. These findings suggest that children with autism are able to detect the gaze of others and pinpoint what they can and cannot see. The results of the current study however suggest that children with ASD may find it difficult to perform some VPT1 tasks.

The current study used a task in which children had to identify who would see a sticker placed on the side of a toy. There are two aspects of the current study which may explain the difference in findings compared to other studies of VPT1.

The first issue is that the toy was covered up during the question part of each trial. Essentially, this prevents the children from using current line of sight to perform the task. The children were asked before each trial began ‘can you see the sticker’, however, it is possible that memory issues may have interfered with the child remembering which view of the sticker that they had originally seen. Research has shown that when memory load is increased in VPT tasks, children with autism in particular begin to show more errors (Reed, 2002).

It is also possible that removing a direct line of sight to the toy caused the children with autism difficulty because the toy was no longer visible. Anecdotal evidence from during the task suggests that the children with ASD may have struggled to represent an object that they could not see. Once the toy was covered, some of the children began to ask where it was, or when asked ‘when I lift the pot up, will you see the sticker’ would reply ‘it’s disappeared’. However, when this occurred the child was also granted a trial in which the toy remained uncovered in which they were still unable to select the correct response. Though unlikely to account solely for the VPT1 difficulties seen in this study, this is an interesting trait that may demand further investigation.

Another issue arising from this study is that the boundary between VPT1 and VPT2 can often appear blurred. In the introduction to this chapter, VPT1 was defined as the ability to understand whether or not a person could see an item, whereas VPT2 is the ability to understand which part of an item someone will see. The two can also be defined in terms of task demands: VPT1 can be completed by relying on the use of dyadic information (Jim can see the bear) whereas VPT2 demands the use of triadic representations (Jim and I can see the bear. Jim can see the front of the bear and I can see the back). The task used in the current study was designed to measure VPT1. However, it is possible that the demands of the task may have tapped into the use of a triadic representation (Jim and I can see the bear. I can see the sticker on the bears arm, Jim cannot). The task could be completed using a line of sight strategy (the sticker on the bear is facing Jim, therefore he can see the sticker), however the use of a triadic representation may have made the task more difficult for the participants with autism. Whilst the use of a triadic strategy would not affect accuracy in the typical children (for whom triadic representations are well developed by age 6 (Baron-Cohen, 1997), it would affect the children with autism.

The ANCOVA showed a significant effect of BPVS on performance. These findings are consistent with previous studies of VPT1 in both typical and autistic children (Hobson, 1984; Warreyn, et al., 2005). This likely relates to the child's ability to understand the instructions given in the task (i.e. 'can Jim see the sticker'). In recent years researchers have begun to develop tasks which are more implicit in nature, which minimises the needs for verbal understanding. Senju, et al. (2011) developed a ToM task in which eye tracking was used to measure false belief prediction in infants. They found that whilst typical children show a pattern of saccades consistent with predicting false belief in others, children with autism do not (Senju, et al., 2010). Implicit VPT1 has also been examined in TD adults by Alloway and Alloway (2010), who found that TD adults automatically encode the viewpoint of a third person (an avatar in the study). Their task showed that interference between the viewer and the avatar occurred when their viewpoints were incongruent, suggesting that the participant was implicitly considering the avatars point of view. These kinds of paradigms would be an interesting way to further explore VPT1 in ASD, as they may be more sensitive to differences between groups.

6.4 Broader Implications

The results of this study demonstrate that children with autism may have difficulty with level one visual perspective taking. There are differences in this task which may account for some of the lack of cohesion with previous finding which may warrant more investigation. Further research is needed into VPT1 in autism to form a clearer picture of this ability and how it relates to different types of person-object representations and types of processing. The development of more implicit VPT1 tasks may offer a better way to tease apart differences between typical and ASD children by providing a way to examine the more automatic aspects of VPT1.

7 General Discussion

7.1 Background to Research

The ability to take another person's visuospatial perspective is a complex social ability which can impact on how we interact with others. VPT allows us to see things from someone else's point of view, which may provide information that makes it easier to judge their mental states (i.e. they are looking at the beer menu, they want to have a beer).

Problems in social interaction are a key deficit in autism spectrum disorder (Frith & Frith, 2007). People with autism are well known to have problems understanding the mental states of others (Abell, et al., 2003; Baron-Cohen, 1995; Baron-Cohen, et al., 1985; Fletcher, et al., 1995; Frith & Frith, 2007; Frith, 2001; Happe, 1995; Senju, 2012); however there has been much debate as to whether difficulties in understanding the visual perspectives of other people could also be a contributing factor in social impairments. Some researchers have argued that the concrete nature of the information available in VPT (the visual feedback on viewpoint) suggests that this ability should be unimpaired in autism (Leslie, 1987). They argue that whilst people with autism struggle to represent abstract information such as mental states, they do not show impairment at representing more concrete information such as visual states. However, other researchers have shown that people with autism are impaired at VPT and that this relates to their mentalising ability (Hamilton et al. 2009).

VPT is a complex ability, drawing on a variety of different processes. Whilst people with autism are known to show impairments in social skills and ToM, is has been unclear whether they may also have problems in VPT and the processes which underlie it. The ability to represent bodies impacts on VPT by providing information on body orientation and what others can see, whereas spatial transformations allow a person to perform the initial transformation that allows them to put themselves in a different place.

This thesis aimed to examine the underlying processes involved in visual perspective taking in typically developing people and people with autism. Specifically, it aimed to investigate the relationship between body representation, spatial transformations and VPT. The studies reported were designed to test whether there were any differences between TD and autistic individuals in regards to these processes and importantly whether these differences could account for problems with VPT in autism. This chapter will begin with a summary of each experiment followed by an interpretation of the findings. It will then delve further into the relationship between the different processes that have been investigated, discussing the implications of the findings in relation to social cognition and interaction.

7.2 Summary of Results

7.2.1 Chapter Two

Chapter 2 investigated whether children with autism have difficulty in the perception of bodies and the ability to draw meaning from body postures. In order to see things from someone else's point of view it is necessary to be able to represent where they are and how their body looks. Thus, difficulty with interpreting the bodies of other people could lead to problems in perspective taking. Previous research had shown mixed findings as to whether people with autism were impaired in perceiving bodies as well as forming knowledge about body postures. The experiment presented in this chapter was designed to tap into both perception and posture knowledge, by examining posture matching of meaningful and meaningless bodies, hands and objects. Results showed no significant differences between the children with autism and the comparison groups at performing the task. All of the children found it easier to match the meaningless stimuli and all performed worse on the body matching task compared to hands and objects. Verbal ability was found to predict performance in all children, with task performance increasing as a better verbal ability developed.

Interpretations

No group differences were found in this study, however there were significant effects of age and verbal ability. Groups were not matched adequately on these variables and so it was difficult to conclude from the data whether the ASD children were truly unimpaired as performance was delayed in relation to their CA but advanced in relation to their VMA. Findings suggest that the ability to perceive a body or gain knowledge about body postures alone cannot explain difficulties in perspective taking in autism, as children were able to perform the task. These findings are consistent with those of Hamilton, et al. (2007) who found that gesture and posture imitation was unimpaired in children with autism compared to TD children. It is worth noting however that in both Hamilton's study and Chapter 2, a younger TD group was used as a comparison. Whilst in Hamilton's study children were matched on VMA, the autism group was older. This means that though the ASD children were performing at the level expected for their verbal mental age, they may not have been performing at the level expected for their chronological age. In chapter 2, an older, lower VMA group of ASD children were compared to younger, higher VMA TD children and a similar age, yet higher VMA group of MLD children. Whilst no significant difference between the groups was found, it is difficult to make any strong claims as to how age appropriate the performance was. Age was found to predict performance in this chapter, and the TD group were limited in age range (4.04-7.94) which may have affected findings.

The aim of this study was not to compare directly matched groups, but to examine where the performance of the ASD children fell in relation to TD children and children with learning difficulties. However it is clear that using a wider age spread of comparison children could be more informative as to how intact body representation is in ASD children relative to their TD peers. Chapter 5 attempted to solve this issue by testing a group of ASD children and VMA matched TD children spanning a similar age range. Meaningful and meaningless bodies only were examined (no objects or hands) and results showed that children with autism performed significantly worse compared to the VMA matched TD children. Though the same stimuli and procedure were used in both of these chapters, the methodology used in data collection differed.

In Chapter 2, a developmental trajectory method was used for data collection. Twenty three children with autism were tested alongside sixteen children with MLD and sixty six TD children. No significant differences were found between any of these groups on meaningful or meaningless hands, bodies or objects. The groups were also found to show similar developmental trajectories for BPVS and accuracy, with performance increasing with verbal ability across all groups. In Chapter 5, thirty children with ASD were compared to thirty VMA matched TD children. Though the groups differed in chronological age (the ASD group had a mean CA of 9.03 whereas the TD group had a mean CA of 6.83) there was no significant difference in verbal ability and the TD children spanned a very similar age range to the ASD children. In this chapter a significant difference was found between the groups, with the ASD children performing worse compared to the TD children. Though the developmental trajectories were similar, the TD children's performance increased with age and BPVS, reaching a consistently high level of performance at around 10 years old or a raw BPVS of 120. In contrast, the ASD children did not reach ceiling level, with even the oldest and most able children still only scoring around 80% correct.

In order to examine the differences between these groups the data was examined more closely. First, to calculate whether the ASD group in chapter 5 were performing worse overall than the ASD group in chapter 2, a t-test was used conducted on the body data only. There were no significant differences in performance between these groups for meaningful ($t(51) = -0.38$, $p = 0.71$) or meaningless bodies ($t(51) = -0.41$, $p = 0.68$). These tests rule out any difference in findings being a result of the ASD group in chapter 5 simply being worse than the group in chapter 2. A t-test was also conducted to analyse whether there were significant differences in performance in the TD groups between chapters 2 and 5. There were no significant differences found for meaningful ($t(94) = 1.29$, $p = 0.20$) or meaningless ($t(94) = 0.89$, $p = 0.37$) bodies.

One explanation for the discrepancy found between the results of these chapters is that differences may be related to the TD control groups used. In chapter 2, an older, lower VMA group of ASD children were compared to a group of TD children with an age range spanning ages

4.04-7.94. In chapter 5, a VMA matched, older group of ASD children were compared to a group of TD children with an age range spanning 6.83-11.35. There were no TD children in the Chapter 2 study older than 8 years old. These findings suggest that in chapter 2 a lack of differences between groups may have been due to the limited and lower age range of the TD group, whereas when a larger age range of TD children were tested differences in performance emerged.

These findings provide compelling evidence for testing a wide an age range as possible when collecting developmental data. Being able to plot the developmental trajectory of an ability is useful, regardless of whether the method used to collect data is focussed on a trajectory approach or matched groups. This is because the changes that occur during childhood can be plotted out clearly and give a clear understanding of how certain abilities develop in both typical and atypical populations.

7.2.2 Chapter Three

Chapter 3 investigated whether adults with autism were able to perform different types of spatial transformations. Egocentric transformations are an essential process for perspective taking (Yu & Zacks, 2010) whilst measuring mental rotation gives us an idea of a participant's general spatial abilities. Results from this study showed that participants with autism were slower, but no less accurate at mental rotation compared to TD participants. On the other hand, performance on the egocentric transformations task showed that participants with autism were both slower and less accurate than the TD participants. These results suggest that people with autism may have particular difficulty with using their own body as a reference frame for spatial transformations. Comparisons across tasks showed that participants with autism performed significantly worse in both the mental rotation and egocentric tasks in regards to both their slope and intercept data.

Interpretations

The group differences found in this study suggest that people with autism find spatial transformations difficult compared to typically developing people. Comparisons across tasks support the notion that the ASD participants have a general perceptual impairment compared to the TD participants.

In the mental rotation tasks this impairment was reflected in response times only as accuracy was normal whereas in the egocentric task participants with ASD showed significantly different response times and accuracy. Differences in accuracy in the egocentric task point to there being a more specific issue with egocentric transformations that people with autism struggle to overcome. A specific difficulty with egocentric transformations would explain why people with autism find taking someone else's point of view difficult. If the underlying transformation you use to put yourself in someone else's place is impaired, then you would expect to see poorer VPT2 performance. These findings are consistent with studies in TD adults, which have shown that people with poorer social skills find it more difficult to perform embodied spatial transformations (Brunye, et al., 2012; Kessler & Wang, 2012; Shelton, et al., 2012).

7.2.3 Chapter Four

Chapter 4 examined the development of level 2 visual perspective taking in typically developing children. Two experiments were conducted. The first experiment investigated whether TD children were able to perform an egocentric perspective transformation. The results confirmed that they were able to do so, which was consistent with previous studies of similar VPT2 abilities (Hamilton). The second experiment examined which other cognitive processes might be related to VPT2 in TD children. Results showed that body representation was related to VPT2 ability. These results suggest that understanding the bodies and postures of other people may be an important skill for perspective taking in TD people. The results of these studies provided a framework to investigate these different processes in autism.

Interpretations

The results of this chapter show that VPT2 develops throughout childhood, improving with age and verbal ability in TD children. In experiment three it was hypothesised that VPT2S may not be predicted by social ability as found in Hamilton et al (2009) as it does not require a representation of another person’s viewpoint. This was confirmed in the results; however the results of experiment four also showed this to be the case for VPT2O. Experiment four showed that VPT2 self and other were highly related. Generally across experiments results showed that VPT2 was predicted by body representation, but not by mental rotation or social skills. The lack of relationship between social skills and VPT2 was a little surprising, as adult studies have shown that TD adults with better social skills also show better VPT2 ability (Brunye, et al., 2012; Kessler & Wang, 2012; Shelton, et al., 2012). In the SAS, scores below 16 have been associated with higher autistic traits (Liddle, et al., 2009). Only two children out of the 76 tested scored below 16 on the SAS, suggesting that most of the children in the sample had good social skills. This lack of variability may be why no relationship between VPT2 and SAS was found. The relationship between body representation and VPT2 is consistent with the literature on perspective taking in adults. In order to perform the embodied transformation into another perspective (Kessler & Thomson, 2009), one must first form a motor representation of the target body (Grush, 2004). Thus, we would expect that those with better body representation skills would be more efficient at perspective taking. The results from the study suggest that this is the case, and that from childhood TD people are able to use the body to inform VPT2.

7.2.4 Chapter Five

Chapter 5 examined VPT2 in children with ASD compared to VMA matched TD children. This study built upon the findings of Chapter 4: having found that body representation was related to VPT2 in

TD children, this chapter aimed to investigate which processes relate to VPT2 ability in ASD children. Previous studies had shown mixed findings as to whether VPT2 is impaired in children with autism. This chapter confirmed findings of impairment, but also revealed that in children with ASD, VPT2 is related to different processes than those found in TD children. Namely VPT2 ability was found to relate to mental rotation ability whereas in TD children it was related to body representation. A link between VPT2 and general social ability was found in the ASD group, suggesting that VPT2 and social interaction are related.

Interpretations

The results found in this chapter suggest that children with autism may not be completing VPT2 in the same way as TD children. These findings may account for why studies of VPT2 in ASD have so far been inconsistent as to whether the ability is impaired. It stands to reason that in some of the studies in which intact VPT2 was found in the children with autism, that they may have been using a different strategy. It is interesting that good mental rotation ability (age appropriate performance) was found in the ASD children in this study, considering that in the adult study we found that the adults with autism were not as good as the TD adults in the mental rotation task. In the adult study however, group differences were found on response times only and not on accuracy. Importantly, in the mental rotation task in chapter 3 there was no effect of group on slope, suggesting that difficulties were not necessarily due to an inability to rotate the stimuli, but with the speed it took the ASD participants to perform each rotation. In the child study (chapter 5) no response time data was collected, and so subtle differences in time taken to perform mental rotation compared to the TD group could not be seen.

The relationship between social skills and VPT2 performance in the ASD group is consistent with the suggestion put forward in the introduction to this thesis that VPT2 is an important skill in social interaction and that people with better perspective taking abilities will be more socially adept. These findings are also consistent with studies of social skills and VPT2 in TD adults with higher autistic traits which again have shown a relationship between social ability and VPT2 performance (Brunye, et al., 2012; Kessler & Wang, 2012; Shelton, et al., 2012). If you are able to see something from another person's point of view, then you should be better at social interaction.

The findings in Chapter 5 raise an interesting question: Does VPT2 require spatial *and* social (i.e. bodies, ToM) abilities? The results seem to suggest that when performance is driven strongly by performance in a purely spatial domain then VPT2 is less accurate. The ability to integrate information from bodies with an egocentric transformation appears to be the most efficient way of performing VPT2. It is clear that multiple strategies are available, as seen with the use of mental rotation in the autism group. However, as found in previous research, perspective taking is most accurate when using an embodied egocentric transformation (Zacks & Tversky, 2005). This provides yet more support for the role of egocentric transformations and body representation in VPT2. Furthermore, they also suggest that the ability to integrate information from these domains, instead of simply rotating the scene, is the most efficient way to perform VPT2. One way to further test this hypothesis is to conduct more studies which focus more on the social or the spatial aspects of VPT. Surtees and Apperly (2012) manipulated the social demands in VPT2 by asking participants how a number would appear to a partner in a joint action task. They found that the partner's visual perspective caused interference in the social condition, but not in the non-social. Another VPT task with strong social demands is Keysar, Lin, and Barr (2003)'s director task. In this task the participants stand behind a shelf holding several items while another person stands in from (the director) and gives instructions of which items to choose. Not all items are visible to the director and so the participant must be able to take the directors perspective into account to avoid choosing items that they cannot see. The authors found that participants were not able to inhibit their own perspective when choosing items and often made incorrect responses. This task has been argued to have a strong ToM component as it relies on the ability to represent someone else's false belief (the director believes the 'big jar' is the one they can see, but there is a bigger jar on view to the participant). Both of these tasks would provide interesting ways of measuring the social components of VPT.

In terms of manipulating the more spatial components of VPT2, Kessler and Thomson (2009) developed a task in which they were able to examine the underlying spatial components present in perspective taking (termed spatial perspective taking, or SPT). Participants were presented with images of a human avatar seated at a table with an item to either side of them (a flower and a gun). The position of the avatar at the table was rotated to be more or less congruent with the position of the participant (providing changes in the angular disparity between the avatar and viewer). Participants had to make laterality judgements in regards to the placements of the items from the avatars viewpoint. The authors found that the larger the angular disparity between the avatar and the viewer, the longer participants took to respond. This demonstrated the underlying spatial transformation that the participant completed in order to put themselves in the place of the avatar, highlighting the importance of spatial mechanisms in perspective taking. The results in this thesis support the findings of this study and those which have shown that poor social skills are related to poor perspective taking (Brunye, et al., 2012; Kessler & Wang, 2012; Shelton, et al., 2012). Furthermore, they suggest that problems in VPT2 in autism are not simply a result of problems in one domain (such as representing two simultaneous but differing viewpoints) but may be related to impairments across a range of processes.

7.2.5 Chapter Six

Chapter 6 aimed to examine VPT Level 1 in children with and without autism. A line of sight paradigm was used in which the child had to decide who would see a sticker placed on the side of a toy: themselves or a doll. The majority of the previous research into VPT1 in autism has shown this ability to be unimpaired (Baron-Cohen, 1989; Hobson, 1984; Reed, 2002; Reed & Peterson, 1990), which has been linked to intact eye direction detection in children with ASD. In the current study, children with autism were significantly less accurate at performing VPT1 than the TD children tested. Whereas the TD group showed ceiling level performance, the ASD group were more variable with accuracy between around 70-80%. A regression analysis also showed that VPT1 in autism was predicted by verbal ability and social skills, whereas in the TD children there was no relationship between VPT1 and body representation, mental rotation, VPT2, BPVS, age and SAS.

Interpretations

The data from this study suggest that children with autism may struggle with VPT1 compared to TD children. However, as discussed in Chapter 6 there are methodological issues which must be considered. In particular, the data from this study raise the question of how the use of dyadic and triadic paradigms affects performance in people with autism. Most VPT1 tasks rely on dyadic representations (i.e. Jim can see the toy) whereas VPT2 tasks use triadic representations (i.e. Jim can see the front of the toy and I can see the back). Whilst research has shown that children with autism appear to be unimpaired at the use of dyadic representations (Warreyn, et al., 2005), they struggle to represent triadic information. The task used in Chapter 6 was designed to measure VPT1 and encourage children to draw upon dyadic representations, however task demands (Jim and I can see the toy, but who can see the sticker?) may have tapped into the use of triadic representations. This could explain the difficulties seen in the autistic group, as most line of sight VPT1 research have shown that children with autism can pass VPT1 tasks. It has also been shown that in TD adults, VPT1 appears to have two different components: an implicit automatic pathway in which the viewpoint of another person is automatically encoded and a more controlled pathway in which the other viewpoint is explicitly considered (Alloway & Alloway, 2010; Surtees, et al., 2012). Research into ToM in autism has shown that people with ASD do not appear to show implicit processing of other peoples beliefs (Senju, et al., 2009). It is possible that this may also be true for visual viewpoints. People with autism may be able to explicitly pinpoint another person's line of sight, but they may not necessarily encode it automatically as shown in TD people. More research is needed into VPT1 in autism to form a more cohesive view of how this ability develops.

There was no relationship found between VPT2 and VPT1 in the regression analysis in either group. These findings are consistent with the suggestion that the two different levels of perspective taking draw upon different processes and representation (Surtees et al. 2012). Whilst VPT1 requires dyadic representations, VPT2 requires triadic representations plus the ability to perform egocentric spatial transformations (Surtees, et al., In Press). These findings add to the debate over what differentiates VPT levels 1 and 2. They also help solve the issue raised in the introduction over how an experiment can be designed to measure one or the other. VPT1 studies should use paradigms which draw upon dyadic line of sight representations, whereas VPT2 should include triadic representations.

Findings from these chapters show that the processes examined alongside VPT (body representation and spatial transformations) do indeed underlie the ability to take another person's perspective. They also demonstrate that people with autism appear to have difficulty with both the underling processes involved in VPT and VPT itself. The following paragraphs will go into further detail on how the processes examined in this thesis may be related and how they contribute towards social interaction.

7.3 How Does VPT relate to the other Processes

In the introduction to this thesis several distinct processes related to VPT were presented. It was thought that spatial transformations impact on VPT2 by providing the means to perform the initial viewpoint transformation, whereas body representation allows the viewer to understand the body of the target and which direction they may be looking. ToM was also discussed, though the relationship between mentalising and VPT was somewhat unclear. The data provided in the experimental chapters has added to the understanding of how these some of these processes are related. It may be useful to think about the relationship between these processes in terms of how social information is processed. It has been suggested that when we view a body (or other social stimuli such as a facial expression) information is processed in a hierarchy (Adolphs, 2003). First the perceptual properties of the stimuli are encoded, such as the position of limbs (I can see a person with arms and legs). Following on, a detailed representation of the stimulus is formed, allowing contextual information to be accessed (the person is reaching towards an apple; they are going to pick it up). Finally, the viewer is able to perform social reasoning, gaining access to mental states (they are going to pick up the apple, they must be hungry). This hierarchical pathway is very linear and inflexible, whereas social information is arguably much more complex and may demand a more flexible processing route. This can be seen in the example of multiple routes for completing processes such as ToM or VPT1, in that they can be done automatically and implicitly or explicitly. Furthermore, results from chapter 5 show that there are different routes to completing the same processes in typical and autistic populations. Whereas TD children are able to use information from bodies and egocentric transformations to complete VPT, children with autism rely on more mental rotation based strategies. Both of these types of processing give access to the same ability (VPT) however it appears that the strategy used by typical children is more efficient as it leads to more accurate responses. In the summary for chapter 5 the idea that successful visuospatial perspective taking integrates both social and spatial information was discussed. Recently, Clements-Stephens, Vasiljevic, Murray, and Shelton (2013) suggested that participants who are more susceptible to social information may better integrate social and spatial aspects of VPT, whereas less socially aware may rely more heavily on the spatial processing. The results of this thesis certainly support this suggestion, however it would make for interesting future research to try and tease apart the components which drive good VPT ability. Clearly people with autism *can* perform VPT using an alternative strategy to that used by TD individuals, but future research could focus on the interaction between the social and the spatial to examine the optimal strategy for VPT completion.

Social reasoning (the final stage of social information processing) is impaired in people with autism (Abell, et al., 2003; Baron-Cohen, 1995; Baron-Cohen, et al., 1985; Fletcher, et al., 1995; Frith & Frith, 2007; Frith, 2001; Happe, 1995; Senju, 2012). Though previous research has shown that people with autism struggle represent other people’s beliefs and desires, there has been much debate as to whether the earlier stages of social information processing could also be impaired. The results of the experiments presented in this thesis suggest that this does indeed appear to be the case in people with autism. Though Chapter 2 did not show any significant differences between groups on a task which measured perception and knowledge of different postures, results from Chapter 3 showed subtle differences in response times, regression slopes and intercepts in people with autism which show that they have underlying perceptual differences compared to TD people. These findings suggest that problems with social reasoning in autism may begin with impairment at lower levels stages of processing.

In addition to understanding how lower level processes might contribute towards deficits in social interaction, the relationship between mentalising and visual perspective taking was of interest. In the introduction to this thesis the relationship between ToM and VPT was highlighted. The relationship between VPT and ToM has been under debate in recent years. Whilst some researchers have suggested that VPT and ToM may be closely related (Farrant, et al., 2006; Hamilton, et al., 2009) others have argued for the two being dissociable abilities (Leslie, 1987). Both of these abilities develop at around the same time (Flavell, 1988) and both tap into the ability to see something from another person's point of view, whether it be physical (VPT) or mental (ToM) (Farrant, et al., 2006; Hamilton, et al., 2009). VPT can certainly be seen to provide information which may aid ToM (for instance, 'She is looking at the sugar bowl. She must think that her tea is not sweet enough') and has also been found to activate the temporo-parietal junction, an area commonly found to be activated by ToM tasks (Aichhorn, et al., 2006). It has been suggested that this commonality is due to visual perspective taking and ToM requiring representations of multiple viewpoints (Aichhorn, et al., 2006). A recent study from Hamilton, et al. (2009) found VPT and ToM were strongly correlated in TD children. These findings suggest that VPT and ToM may share some similar underlying cognitive mechanisms in TD people. In Chapter 5 of this thesis the relationship between ToM and VPT2 was examined in people with ASD. The results of the study conducted in this chapter found no correlation between ToM ability and VPT2 performance in the ASD group. It has been suggested that though VPT and ToM may be related in TD children, this may not be the case in children with autism. Tan and Harris (1991) found that children with autism were able to perform VPT even in the face of significant ToM impairments. They argued that as previous research had shown that people with ASD may not complete ToM tasks in the same way as TD people, it was also possible that the same may be true for VPT. The results of Chapter 5 support this suggestion, showing that whilst TD people show a relationship between body representation and VPT2 ability, VPT2 in autism appears to be driven by the use of an object based rotation strategy. From the data gathered in this thesis, I am not able to confirm what kind of processes may be driving differences in ToM in autism. However, the fact that people with autism are impaired at both suggests that they may have issues simultaneously representing the viewpoints (mental states and visuospatial) of themselves and others. Further research into the relationship between ToM and VPT in people with and without autism would be very useful.

7.4 Broader Implications for Autism Research

The findings presented in this thesis provide a strong case for deficits in social interaction in autism being related to broader issues regarding the processing of social information related to the self and others. In the field of autism research there has been a strong focus on social information processing related to faces, emotions, eye gaze and mental states. However, the results of the studies presented here suggest that the contribution of body processing, spatial skills and visuospatial perspective taking are also worth taking into consideration when attempting to explain why people with autism find social interaction so difficult. There are several questions arising from this thesis which remain unanswered, and which motivate further research into the processes underlying VPT in autism. Firstly, the experiments in Chapters 4 and 5 implicitly measure the ability to perform an egocentric transformation into another person's viewpoint. However, it would be interesting to look explicitly at how egocentric transformations and VPT2 are linked in people with autism. Performance on tasks such as those used in chapter 3 could be directly compared to the ability to perform VPT. This would give a clear indication of how mental rotation and egocentric transformations relate to VPT2 in adults with autism, and which is the strongest driving factor in this ability. It is also clear that more research is needed into body representation in different groups of ASD participants. By testing both high and low functioning children and adults we can begin to build a clearer picture of these abilities and whether they are impaired. Research into implicit VPT1 in autism would also be useful and would inform us as to whether VPT1 develops in the same way in people with ASD as it does in TD individuals. Different tasks could also be examined to further investigate the importance of dyadic versus triadic representations in VPT and how this influences performance in autism.

On a more practical note, the findings of this thesis suggest that social skill interventions in autism may find it useful to focus on abilities such as body representation and understanding and visuospatial perspective taking in order to improve social communication. Many interventions in autism focus on understanding emotions using facial expression and gaze following, however it can be seen that people with autism also have impairments on using the bodies of themselves and others which may impact on social interaction.

7.5 Conclusions

The work in this thesis show that whilst TD people are skilled at seeing things from someone else's point of view, people with autism struggle with this ability. The results of the studies conducted in this body of work suggest that this difficulty is based upon problems with transforming the self to match another point of view, and to some degree difficulty with representing the bodies of other people. On a wider scale, the results presented here suggest that impairments in social interaction in people with autism are not simply due to problems with representing other's mental states, but also their viewpoints and bodies. These findings are consistent with studies which have examined the link between social skills and perspective taking in TD people, showing that those with poorer social skills and higher levels of autistic traits also tend to be worse at embodied spatial transformations and taking another perspective. The studies in this thesis further our understanding of how perspective taking develops and the mechanisms which underlie this ability in both typically developing and autistic participants. They also provide a framework for beginning to think about social impairments in autism on a broader scale, including more perceptual and spatial difficulties as a core contributor in social interaction difficulties.

8 References

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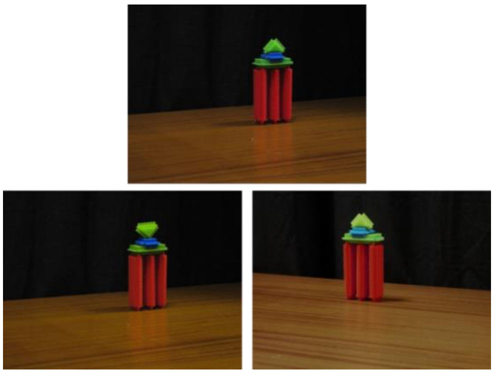
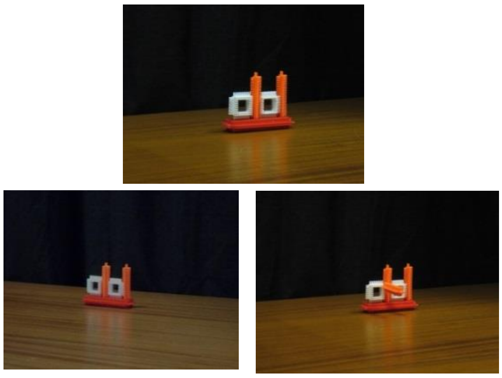
9 Appendices

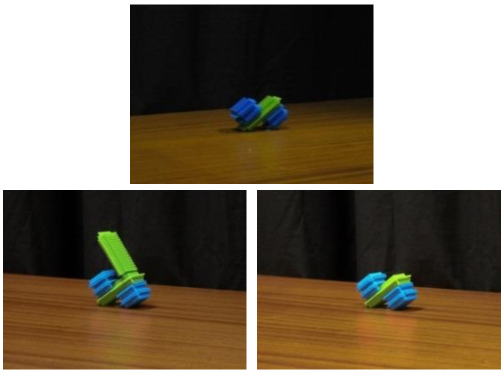
Appendix A:

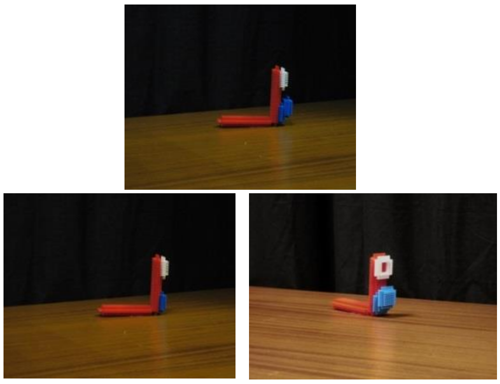
Stimulus sets from experiment 1.

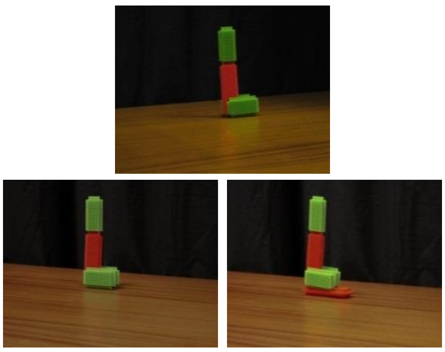
Meaningless Objects

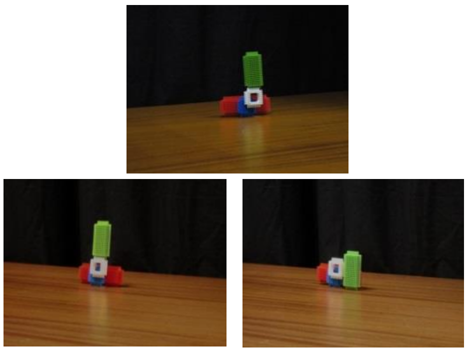












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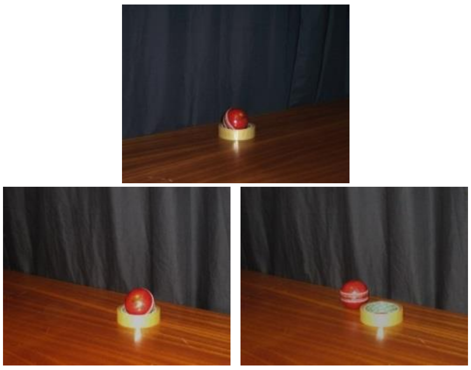
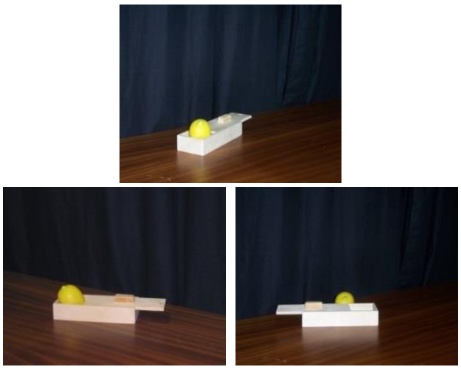
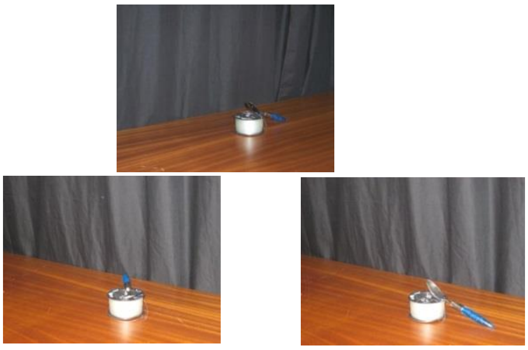
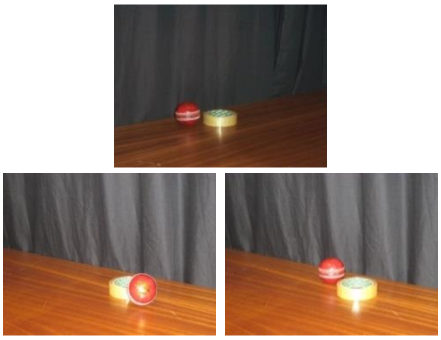
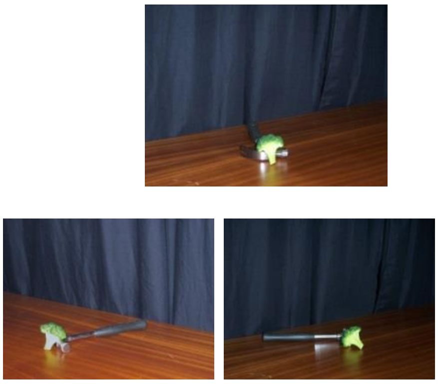
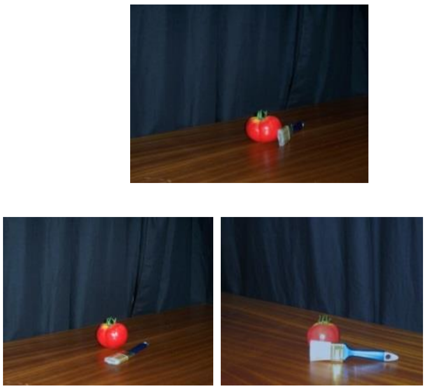






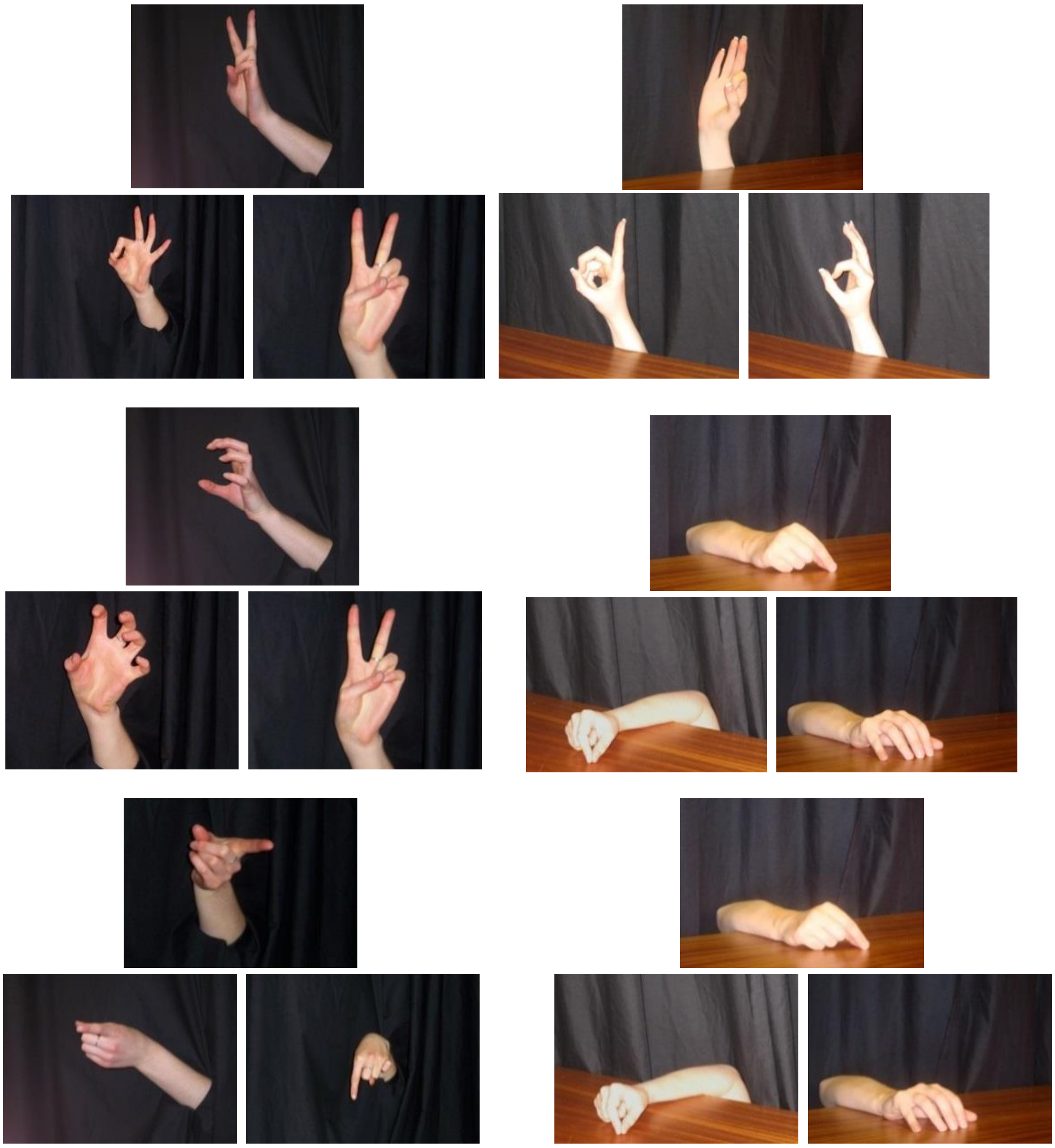






Meaningless Hands

Meaningful Hands



Meaningless Bodies

Appendix B

Stimulus sets from Experiment 2

Body stimuli

Car stimuli

Appendix C

Stimulus sets from Experiment 3

Teddy

Stimulus sets from Experiment 4 (Plus toys used in experiments 5 and 6)

Teddy

Fire Truck

Frog

Appendix D

Example of the theory of mind record sheets used in experiment 5

1)	**Diverse Desires: Snacks** (sheet needed)	
	This is Mandy. It's snack time so Mandy wants something to eat. Here are two different snacks: carrots and cakes. **Own desire: Which snack would you like best?**	Carrots / Cakes
	Well, Mandy really likes [the other one]. She doesn't like [child's choice]. She likes [the other one] best. So, now it's time to eat. Mandy can only chose one snack. **Test: Which snack will she chose?**	Carrots / Cakes
	Reality control: Which snack does Mandy like best?	Carrots / Cakes
2)	**Diverse beliefs: Cat** (sheet needed)	
	This is Linda. Linda wants to find her cat. Her cat might be hiding in the tree or it might be hiding in the garage. **Own belief: Where do you think her cat is hiding?**	Tree / Garage
	Well, that's a good idea but Linda thinks her cat is hiding in the [other place]. **Test: Where will she look for her cat?**	Tree / Garage
	Reality control: Where does Linda think her cat is hiding?	Tree / Garage
3)	**Knowledge access: Crab** (props needed)	
	I have a box here. Show child closed box. **Own belief: What do you think is inside this box?**	
	Open box and show the crab to the child. Put crab back in box and replace lid. **Own knowledge: What's inside the box?**	Crab
	Polly has never seen inside this box before. Now here she comes. **Test: Does Polly know what's inside the box?**	Yes / No
	Reality control: Has Polly seen inside the box?	Yes / No
	Memory control: When I first showed you the box, what did you think was inside?	Crab
4)	**Explicit False Belief: Gloves** (sheet needed)	
	This is Scott. Scott wants to find his gloves. They might be in his rucksack or they might be in his drawers. Scott's gloves are really in his rucksack but Scott thinks they're in his drawers.	
	Test: Where will Scott look for his gloves? **Why will he look there?**	Rucksack / Drawers
	Reality control: Where are his gloves really?	Rucksack / Drawers

5)	**Contents False Belief: Smarties** (props needed)	
	Show child sealed Smarties tube. **Own belief: What do you think is inside?**	smarties
	Let's have a look. Open tube and show that it actually contains a pencil. Put pencil back in tube and replace lid. **Own knowledge: What's inside the tube?**	pencil
	In a minute your friend X is going to come in. He hasn't seen this tube yet. When he comes in I'm going to show him this tube, closed up just like this. I'm going to ask him 'What's in here?' **Test: What will X say?** **Why will he say that?**	Smarties / Pencil
	Reality control: What is really inside?	pencil
	Memory control: When I first showed you the tube, what did you think was inside?	smarties / pencil
6)	**Implicit False Belief: Sally-Ann** (props needed)	
	This is Sally and this is Ann. Sally has a basket and Ann has a box. Sally has a marble and she puts her marble in her basket to keep it safe. Then she goes out. While Sally is out, naughty Ann takes Sally's marble out of her basket and she puts it in her box. Here comes Sally. **Test: Where will Sally look for her marble?** **Why?**	Basket / Box
	Reality control: Where is the marble really?	Basket / Box
	Memory control: Where did Sally put the marble in the beginning?	Basket / Box

7) Penny Hiding

We're going to play a little hiding game, one that you probably know already.
I'm going to hide this coin in one of my hands.
Hide a coin behind your back and bring hands out again as two closed fists.
Which hand is the coin in?
Always use **R L R R L R**

Repeat 6 times: (which hand guessed) ____ ____ ____ ____ ____ ____

Then say; *"Now it's <u>your</u> turn. See if you can trick me. Hide it really well, just like I did".*
Get child to do this 6 times, and note down how successful each trial is:-

Trial	**1**	**2**	**3**
Which hand?			
Does child hide *both* hands behind back? (-1)			
Does the child bring *both* hands forward? (-1)			
Are hands closed? (-1)			
Is the coin hidden? (-1)			
Asymmetric hands? (-0.5)			
Tricks used?			

Comments: