RESEARCH ARTICLE

Cognitive Mechanisms Underlying Visual Perspective Taking in Typical and ASC Children

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Previous research has suggested that people with Autism Spectrum Conditions (ASC) may have difficulty with visual perspective taking (VPT) but it is not clear how this relates to different strategies that can be used in perspective taking tasks. The current study examined VPT in 30 children with autism and 30 verbal mental age matched typical children, in comparison to mental rotation (MR) abilities and body representation abilities. Using a similar paradigm to Hamilton, Brindley, and Frith [2009] all children completed three tasks: a VPT task in which children decided what a toy on a table would look like from a different points of view; a MR task in which the child decided what a toy would look like after it had been rotated; and a body posture matching task, in which children matched pictures of a body shown from different viewpoints. Results showed that children with ASC performed better than the typically developing children on the MR task, and at a similar level on the VPT task and body matching task. Importantly, in the typical children VPT performance was predicted by performance on the body matching task, whereas in the ASC children VPT performance was predicted by MR ability. These findings suggest that differences in VPT in ASC may be explained by the use of a spatial rotation strategy rather than the embodied egocentric transformation strategy used by typical children. ***Autism Res** 2015, 00:000–000*. © 2015 International Society for Autism Research, Wiley Periodicals, Inc.

Keywords: autism spectrum conditions; visual perspective taking; mental rotation; embodied; cognitive mechanisms

Introduction

When two travelers peer at a map from different locations, both can see the streets but it may take extra consideration to realize that "ahead" to one viewer is "left" to the other. Visual perspective taking (VPT) is the ability to consider another person's viewpoint on the world and is traditionally divided into level 1 VPT (can she see the object?) and level 2 VPT (what does it look like to her?) [Flavell, Everett, Croft, & Flavell, 1981]. VPT2 is the process which the two map-readers must engage in to communicate effectively—it draws on both spatial skills to consider the map and social skills to consider what representations are in the other's mind. Recent research has shown that children with autism spectrum conditions (ASC) perform worse than expected on a VPT2 task [Hamilton, Brindley, & Frith, 2009] compared to typically developing (TD) children. In this article, we explore and expand on this result with a new study which examines the strategies underlying VPT performance in typical and autistic children.

Taking another visual perspective is a complex task which draws on a number of different cognitive processes [Surtees, Apperly, & Samson, 2013a]. Different people (or the same person in a different context) may use different cognitive strategies to accomplish the same task [Gardner, Brazier, Edmonds, & Gronholm, 2013; Kessler & Wang, 2012]. In the VPT2 task used by Hamilton, et al. [2009], children aged 4–12 years were shown four pictures of a toy (e.g., a cow) from four canonical orientations and asked to point to the picture that matched the orientation of the same toy on the table. The real toy was then covered, and a doll was placed to the left or right of the toy. The child was then asked "which cow will the doll see?" and answered by pointing to one of the cow pictures. To give a successful response on this task, the child could adopt a strategy of an embodied egocentric transformation (EET), and imagine herself in the place of the doll to see the world through the doll's eyes. This strategy draws on the ability to manipulate body representations and may be related to other social skills [Kessler & Rutherford, 2010; Kessler & Wang, 2012]. Alternatively, the child could adopt a strategy of mental rotation (MR), and imagine the hidden toy turning around so that the side that was in front of the doll is now in

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Published online 00 Month 2015 in Wiley Online Library (wileyonlinelibrary.com)
DOI: 10.1002/aur.1501

front of the child. She can now consider her own new view of the imagined toy to answer the question [Zacks & Tversky, 2005]. This strategy draws on the ability to mentally transform objects in space. Both strategies can lead to the correct answer in this task but they draw on quite different cognitive systems [Surtees, et al., 2013a].

There are a number of reasons to believe that people with autism may find EET difficult. Autism is characterized by difficulties with social cognition, in particular theory of mind (ToM) [Frith, 2001, 2012; Happe, 1995; Senju, 2012]. Neuroimaging [Schurz, Aichhorn, Martin, & Perner, 2013] and cognitive [Surtees, Apperly, & Samson, 2013b] studies suggest links between the ability to consider another person's thoughts and taking their visual perspective. Previous studies of VPT2 in ASC did not examine the specific strategy children might use. Out of three studies conducted on VPT2 in autism, two studies have reported poor VPT2 in children with ASC [Hamilton, et al., 2009; Yirmiya, Sigman, & Zacks, 1994] while one reported intact performance [Tan & Harris, 1991].

In their 2009 study, Hamilton et al. examined VPT2 alongside MR and ToM ability in children with autism and a group of verbal mental age (VMA) matched TD children. They found that in TD children, VPT2 performance is predicted more strongly by ToM ability than it is by MR skills and verbal IQ. Results also showed a task by group interaction, where children with ASC were significantly worse on the VPT2 trials than the typical children, but performed better on the MR task. However, floor effects in this study make it difficult to make strong claims about the direction of results. In this article, our aim is to expand on Hamilton's past work and examine the strategies which typical and autistic children might use to perform VPT2. Two secondary aims are to replicate previous findings [Hamilton, et al., 2009] without floor effects, and investigate whether manipulating the wording of the test question, in regards to VPT2 for self and other viewpoints would impact on performance.

The current study is concerned with two possible strategies—a MR strategy and an EET strategy. Several studies suggest that typical adults use an EET strategy to perform VPT2 tasks [Surtees, et al., 2013a; Yu & Zacks, 2010]. This process involves representing the body posture and position of the target and then mentally transforming the self to match that target [Grush, 2004; Kessler & Thomson, 2009]. Body information is critical in this process [Kessler & Thomson, 2009]. Thus, if children use an EET strategy to perform VPT2, we would expect their performance to correlate with their ability to perform other types of body transformation. To measure body transformation abilities in children, we use a posture matching task [Pearson, 2014]. In this task, children must match a photo of a person in a particular posture to a photo of the same person in the same posture taken from a different viewpoint. To solve the task, the child must create a viewpoint independent representation of the body posture and manipulate it. We predict that children who are good at body posture matching will also be good atVPT2, if those children use an EET strategy. This is likely to be the case for the TD children based on previous research [Zacks & Tversky, 2005].

However, previous research has indicated that people with autism may have impaired body representations [Eigsti, 2013] and are impaired at EET [Pearson, Marsh, Hamilton, & Ropar, 2014]. Thus, children with ASC may find it hard to use an EET strategy. An alternative strategy that children could use is to perform MR on the scene [Zacks & Tversky, 2005]. Zacks and Tversky [2005] found that typical adults could use a MR strategy to complete a perspective taking task, but this strategy was less efficient than performing an EET. A child using a MR strategy could ignore body postures and simply imagine the scene rotating until the part nearest the other viewer is closest to the child. This strategy is very similar to the control task of MR used here and previously [Hamilton, et al., 2009]. We predict that children who are good at MR will also be good at VPT2 if those children use a MR strategy. This is likely to be the case for the children with ASC based on the assumption that they find EET problematic [Pearson, et al., 2014]. To summarize, we predict a relationship between VPT2 performance and body representation in the TD group, and a relationship between VPT2 performance and MR in the ASC group.

In addition to examining the strategy used to perform VPT2, we were interested in whether manipulating the test question would impact on performance in the ASC and TD children. VPT2 studies typically ask about what another person would see from a different viewpoint, but participants could also be asked "what would *you* see if you were at a different viewpoint." Considering the mental states of another and the mental states of the self may draw on similar cognitive processes [Frith & Happe, 1999]. Here we test if this applies to VPT. Previous studies in TD adults have shown little difference behaviorally between the ability to see things from someone else's point of view versus seeing things for oneself from a new point of view [Kessler & Thomson, 2009] as they both require the simultaneous representation of two different viewpoints. However, these different subtypes of VPT2 (VPT2 for self and other) have not been examined in people with ASC. It is possible that those with ASC might find it easier to represent their own view from another location than imagining another person's viewpoint. Alternatively, they might find it equally difficult as judging another person's visual perspective.

Table 1. Participant Demographics

	N	Age	VMA	BPVS Raw	SCQ	SAS	ToM
ASC	30 (27 male)	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 (18 male)	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 $(18 - 36)$	–
		$t(58) = -4.65$, $P < 0.001$	$t(58)=0.23$, $P = 0.82$	$t(58)=0.16$, $P = 0.87$		$t(56)=10.99$, $P<0.001$	

All data are given as mean ($\pm$standard deviation) and range.

Thus, we modified Hamilton's VPT2 task to include two different conditions. One measured perspective taking for another person, VPT2 other (VPT2O). This was used in the original study ("what will Suzy see?"). Additionally, we added a condition to measure perspective taking for self, VPT2 self (VPT2S), asking "what would you see if you were sitting over there." This meant that it was possible to examine whether these subtypes of VPT2 were different in children with and without autism. Based on previous findings we predict that children with ASC will be impaired on VPT2 tasks compared to the TD children (as both require an EET), but that MR performance will be intact.

Method

Participants

Sixty children participated in this study. Thirty children with a diagnosis of ASC were recruited from schools in Nottinghamshire and Wales. Their mean chronological age (CA) was 9.27 years and 27 were male. The British Picture Vocabulary Scale (BPVS) [Dunn, Dunn, Whetton, & Burley, 1997] was used to establish VMA and the Social Communication Questionnaire (SCQ) [Berument, Rutter, Lord, Pickles, & Bailey, 1999] and Social Aptitude Scale (SAS) [Liddle, Batty, & Goodman, 2009] were completed by a caregiver to evaluate the child's social understanding and communication skills. All of the ASC children had a previous diagnosis from an independent clinician, confirmed by the parent/caregiver in a background questionnaire. The task was also completed by 30 VMA matched TD children (see Table 1). They had a mean CA of 6.83 years and 18 were male. The TD children were recruited during Nottingham University's Summer Scientist Week, an event where children take part in several research studies. All TD children completed the BPVS and their caregiver completed the SAS. None of the typical children had a diagnosis of ASC 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.

Design and Procedure

A repeated measures design was used to examine the effects of task on performance (here measured in terms of accuracy). Each child completed four experimental tasks: MR, VPT2 self (VPT2S), VPT2 other (VPT2O), and body representation. Performance on each task was measured by calculating number of trials correct, which was transformed into a percentage. Children with ASC also completed a ToM battery and their parents completed the SCQ/SAS. The ASC children were tested individually in a quiet room at school or at home whereas the TD children were tested individually in a quiet, partitioned cubicle at the Summer Scientist event. The tasks administered were:

VPT2 and MR tasks. These tasks were closely based on Hamilton, et al. [2009]. Materials were a small turntable, an opaque pot and three toys (a bear, a frog and a small fire truck). The turntable was marked with a square with different colors on each side (See Fig. 1). The experimenter sat beside the child at the table, and three empty chairs marked with colored stickers were placed around the table. At the start of each trial, the toy was placed on the turntable facing one of the colored strips. The child held a picture card showing four images of the toy from different viewpoints and was asked "which picture can you see?" (Fig. 1a). This established that the child was attending to the initial orientation of the toy. For the VPT2S trials the toy was covered with an opaque pot and the child asked "if you were sitting at the [blue] side of the table (indicating the empty chair with a blue sticker), which picture would *you* see when I lift up the pot?" (Fig. 1b). For the VPT2O task the toy was covered with the opaque pot and a doll was placed at another side of the table. 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. 1c). Other colors were substituted as appropriate, to test the alternative viewpoints. For the MR trials the toy was then covered with an opaque pot, and rotated to a different orientation. The child was then

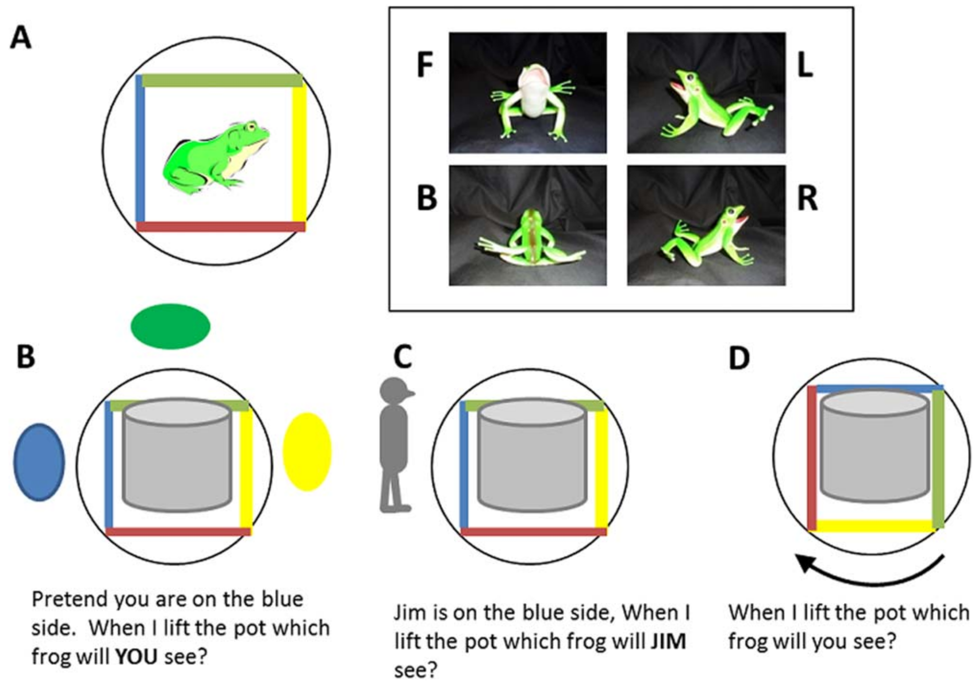

Figure 1. Examples of stimuli and tasks. (A) The toy place on the turntable and an example of a response card given to the child. The toy is then covered. (B) VPT2S: What will YOU see? (C) VPT2O: What will JIM see?, and (D) the MR task, in which the toy is rotated and the child is asked which view they will see when the pot is lifted.

asked "when I lift the pot up, which picture will *you* see?" (Fig. 1d). In all trials, the child could respond by selecting the corresponding picture on the answer card (Fig. 1e). Praise was given for all answers.

Each child completed six trials of the VPT2O task, six trials of the VPT2S task and six trials of the MR task. Trials were blocked by task, and task order was counterbalanced across participants. For the VPT2 tasks the six trials presented were a selection of the three different table viewpoints in a pseudo randomized order (each viewpoint was presented twice) used in combination with each of the four viewpoints of the toy (i.e., front of the toy is facing Jim, Jim is sat on the red side of the table). For the MR task the six trials presented were a pseudorandom selection of the four different viewpoints of the toy and four different starting points for rotation. For each correct answer a score of 1 was given and these were averaged to give a percentage of correct scores for each participant.

Body representation task. The body representation task assessed children's ability to match pictures of human body postures across different orientations. Both meaningful and meaningless postures were used to determine if meaning or familiarity impacts on performance, as previous studies have used a mixture of both meaningful and meaningless stimuli, leading to inconsistency in findings [Dowell, Mahone, & Mostofsky, 2009; Ham, Corley, Rajendran, Carletta, & Swanson, 2008; Hamilton, Brindley, & Frith, 2007; Reed, Beall, Stone, Kopelioff, Pulham, & Hepburn, 2007]. Stimuli defined as "meaningful" depicted familiar postures, that is, communicative postures such as extending an arm to communicate "stop" (see Fig. 2a) whereas for "meaningless" stimuli, unfamiliar postures were used (i.e., a random limb configuration, see Fig. 2b). Body pictures were generated by taking two simultaneous photographs of a clothed person in a distinctive body posture from two different locations. For each matched pair, a foil picture showing the same person performing a different posture was also presented. Pilot testing on adult participants was used to equate difficulty between the different stimuli [Pearson, 2014]. Thus, stimuli on each trial consist of a trio of images—exemplar, target and foil (Fig. 2). These images were printed in color on laminated cards. 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 (Fig. 2).

On each trial, the child was first given a laminated card with two pictures (the target and foil) then given a second laminated card with a single picture (the exemplar). The experimenter asked "which one of these (point to double picture card) matches your picture?" The child could respond either verbally or nonverbally

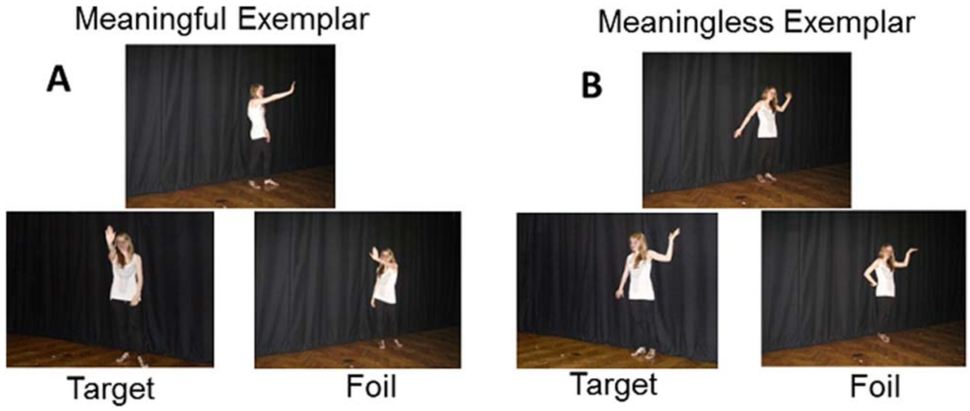

Figure 2. An example of a trial in the body posture representation task, with exemplar, target and foil stimuli. (A) An example of a meaningful trial and (B) an example of a meaningless trial

by pointing or putting the single card with the appropriate match. One practice trial with a different posture was given prior to the experimental trials, 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). Stimuli were presented in blocks because mixing meaningful and meaningless stimuli reduces the impact of meaning [Tessari & Rumiati, 2004]. The order of trials within a block was pseudorandomized across children and the order of blocks (meaningful and meaningless) was counterbalanced. Praise was given throughout regardless of response. For each correct answer a score of 1 was given and these were averaged to give a percentage of correct scores for each participant.

Theory of mind battery. All ASC children were tested on their ToM ability. They were assessed on their understanding of diverse desires and beliefs, knowledge access, false belief, contents false belief and a penny hiding task [Baron-Cohen, Leslie, & Frith, 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, with 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.

Results

VPT and MR Performance

The original study from Hamilton, et al. [2009] compared the performance of an ASC and TD group on MR and VPT2O tasks. To examine whether results from this study replicated previous results, an Analysis of Covariance (ANCOVA) was used to examine performance on MR and VPT2O in the ASC and typical groups. Each child's score on the MR and VPT2O tasks were entered as repeated measures factor, with group, BPVS-raw score and SAS score as additional predictors. SAS was included in the analysis to test for relationships between parent-rated social function and our tasks. Results showed a marginal effect of group (F (1, 54) = 3.366, $P = 0.066$) with the TD children performing worse than the ASC children (Fig. 3) and a significant interaction between task and group (F (1, 57) = 5.924, $P = 0.018$). Here the typical children scored worse on MR compared to the ASC group (t (58) = −2.11, $P = 0.039$) but showed similar performance on the VPT2 other task (t (58) = −0.349, $P = 0.728$). This replicates the results found in Hamilton, et al. [2009]. There was no effect of task and no interaction between task and BPVS. There was a marginal interaction between task and SAS (F (1, 54) = 3.042, $P = 0.087$) showing that accuracy increased with SAS score. There was a

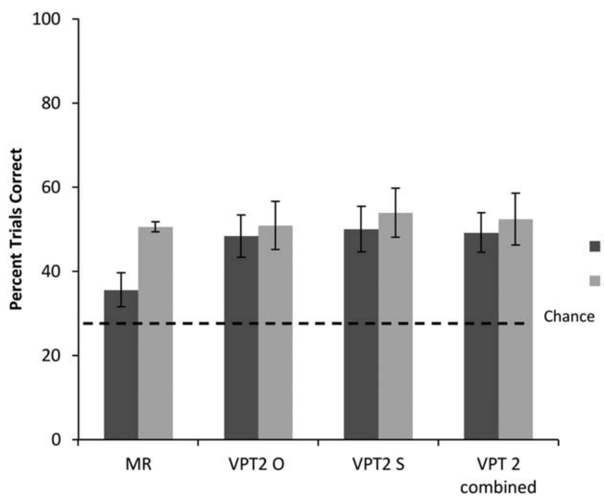

Figure 3. Mean scores (±standard error) for the TD and ASC children across the VPT and MR tasks. Each child completed 6 trials so the maximum score for each task was 6 and chance 1.5 (25%). Results are displayed here as a percentage.

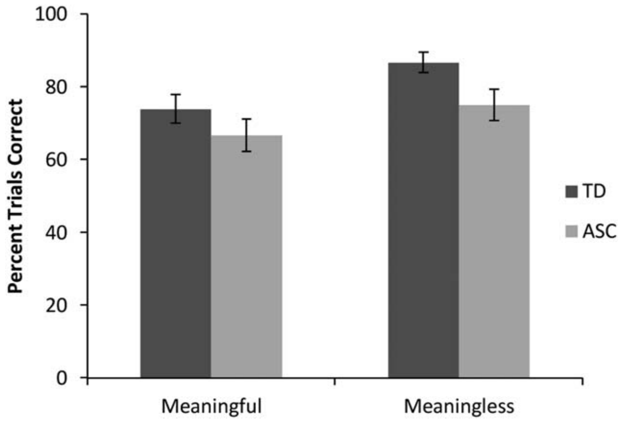

Figure 4. Mean scores (±standard error) for the TD and ASC children in the Meaningful and Meaningless body representation tasks. Each child completed 6 trials so the maximum score for each task was 6 and chance 1.5. Results are displayed here as a percentage.

significant effect of BPVS, with those with higher BPVS scores performing better on the tasks (F (1, 54) =36.879, $P<0.001$). No further interactions were found.

The current study included separate tasks to measure VPT2S and O. To examine whether performance on VPT2S and VPT2O was similar in the two groups, an ANCOVA was conducted with group as a between-subjects variable and BPVS raw score and SAS as covariates. The ANCOVA showed that there was no significant effect of task (P=0.496) and no interaction between task and group (P=0.684), suggesting that VPT2 self and VPT2 other are very similar processes in both ASC and TD participants. To further investigate this relationship a bivariate correlation was performed, with VPT2O and VPT2S as inputs. This showed that VPT2S and O were highly correlated across children (r=0.65, $P<0.001$), therefore they were collapsed to give a single VPT2 score for each child. This was used in further analysis.

To determine the effect of group on VPT2 (overall) and MR performance, an ANCOVA with a between-subjects variable of group, task as a repeated measure and covariates of BPVS raw score and SAS was conducted. Results showed a significant effect of group (F (1, 54) =4.551, P=0.037) with the ASC group performing better than the TD group (Fig. 3). 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 MR than the ASC group (t (58) =−2.11, P=0.032), but no difference between groups on the VPT2 task (t (58) =−0.431, P=0.668). There was a significant effect of task (F (1, 54) =5.330, P=0.025) with both groups more accurate on the VPT2 task than MR. There was also a significant effect of BPVS raw score (F (1, 57) =40.998, $P<0.001$) in that children with a higher BPVS raw score were more accurate but no interaction between task and BPVS (F (1, 54) =2.592, P=0.113). There was no significant effect of SAS (P=0.204), however, there was a marginal interaction between task and SAS (F (1, 54) =3.214, P=0.079) showing that as SAS score increased, accuracy also increased across tasks.

Body Representation Task

An ANCOVA was used to examine the effects of group and stimulus category (meaningful/meaningless) on accuracy, with raw BPVS and SAS entered as covariates. There was a significant effect of meaning (F (1, 54) = 8.31, P=0.006) with both groups showing higher accuracy for the meaningless stimuli (Fig. 4) and a marginal effect of SAS (F (1, 54) = 3.45, P = 0.069) with higher SAS participants performing better than low SAS participants. There was a significant effect of BPVS (F (1, 54) = 18.84, $P<0.001$) with higher BPVS participants performing better. There were no significant effects of group and no interactions between any of the variables (all $P>0.01$)

Which Factors Predict VPT2 Performance in ASC and TD Children?

Separate regression analyses were used to test which measures predicted VPT2 performance in the typical and ASC children. Data for the 30 TD children were entered into a multiple linear regression model testing how VPT2 was predicted by MR, body representation, SAS, BPVS raw score and age. The regression model had an overall fit of R^2=.65. Performance on VPT2 was significantly predicted by performance on the BPVS (β=0.385, $P<0.038$) and body representation task (β=0.458, P=0.011) in the TD children.

Data for the 30 ASC children were also entered into a multiple linear regression model to determine how VPT2 was predicted by MR, body representation, SAS, BPVS and age. The regression model had an overall fit of R^2=0.73, and VPT2 was significantly predicted by performance on the BPVS (β=0.473, P=0.012) and MR task (β=0.661, $P<0.001$). A further regression analysis examined the additional variables collected only in the ASC group. Here ToM and SCQ were entered alongside MR, body representation, SAS, BPVS and age as predictors. The regression model had an overall fit of R^2=0.78, and VPT2 was significantly predicted by performance on the BPVS (β=0.392, P=0.043), MR task (β=0.597, $P<0.001$) and SCQ (β=−0.311, P=0.048). Details of the regression analyses are presented in Table 2.

Discussion

The main aim of the current study was to investigate the cognitive processes involved in taking another person's visual perspective. Results showed that in children

Table 2. Results of the Regression Analyses for the TD and ASC Groups

	Typical	ASC (model 1)	ASC (model 2)
N	$N = 30$	$N = 30$	$N = 30$
Overall model fit	$R^2 = 0.65$	$R^2 = 0.73$	$R^2 = 0.78$
MR performance	0.091 (−0.261 − 0.472) t =0.593 $P = 0.558$	**0.661 (0.323−0.880) $t = 4.48$ $P = 0.000$**	**0.585 (0.278−0.824) $t = 4.22$ $P = 0.000$**
Body Representation	**0.458 (0.191−1.30) $t = 2.77$ $P = 0.011$**	−0.096(−0.621 − 0.306) $t = -0.706$ $P = 0.488$	−0.052 (−0.557 − 0.386) $t = -0.379$ $P = 0.709$
SAS	−0.053 (−1.81 − 1.21) $t = -0.414$ P=0.683	−0.100 (−2.06 − 0.916) $t = -0.795$ P=0.435	0.085 (−1.35 − 2.31) $t = 0.550$ $P = 0.558$
BPVS raw score	**0.385 (0.033−1.02) $t = 2.20$ $P = 0.038$**	**0.473 (0.173−1.14) $t = 2.82$ $P = 0.010$**	**0.370 (0.077−1.10) $t = 2.41$ $P = 0.026$**
Age	0.021 (−6.28 − 6.93) $t = 0.102$ $P = 0.920$	−0.114 (−5.10 − 1.96) $t = -0.924$ $P = 0.366$	−0.087 (−4.56 − 2.20) $t = -0.737$ $P = 0.470$
ToM	Not included	Not included	0.106 (−0.978 − 2.32) $t = 0.848$ $P = 0.406$
SCQ	Not included	Not included	**−0.319 (−2.65−0.010) $t = -2.10$ P=0.048**

Beta values, confidence intervals, *t* values, and *P* values are displayed for each variable. Bold values highlight significant predictors of VPT2 ability.

with autism, MR ability predicts VPT2 performance whereas in typical children body representation ability predicts VPT2 performance. We also replicated the findings of Hamilton, et al. [2009] without the floor effects. Here we consider each of our three tasks (VPT2, MR, and body matching) individually and then consider what our results mean for overall theories of VPT and social cognition in autism.

Individual Tasks

The VPT tasks required the child to consider what a toy looks like from another person's point of view (VPT2O) or what a toy would look like if the child were in a different place (VPT2S). Performance on the self and other tasks was highly correlated across children, suggesting that both types of VPT draw on the same cognitive processes in each child. This parallels findings for ToM, where imagining the mental states of others or the future self are similar [Frith & Happe, 1999]. However, this does not mean that all children use the same strategy (see discussion of group differences in strategy below). Overall, children with and without ASC performed at a comparable level on the two VPT2 tasks. This is consistent with Hamilton, et al. [2009], where performance was similar for children with ASC and VMA matched typical children. However, the present study avoids the floor effects seen in the previous study, and thus confirms more clearly that children with ASC can perform a VPT2 task at a level appropriate for their VMA.

The MR task requires the child to consider what a toy will look like after it has been rotated. Results from this task showed that the TD children performed significantly worse than the ASC children, which is consistent with previous work [Hamilton, et al., 2009] but again avoids floor effects. This is also consistent with a recent meta-analysis [Muth, Hönekopp, & Falter, 2014] and with previous studies showing that people with autism often display better performance on nonverbal measures of performance compared to their verbal ability [Joseph, Tager-Flusberg, & Lord, 2002]. One alternative explanation for these differences between groups is the difference in gender ratio. There were more females in the TD group than the ASC group and previous research has shown that males tend to out-perform females on MR [Geiser, Lehmann, & Eid, 2008]. However, we found no difference in performance between male and female participants both within and across groups in the MR task. This makes it unlikely that gender was a stronger predictor of performance than group. Overall, we suggest that the ability to perform MR in ASC is better relative to younger mental aged matched controls.

The body representation task required children to match images of body postures across different viewpoints. Results revealed no significant effect of group on performance, however there was a significant effect of SAS. Children with higher SAS scores (the majority were the TD children, see Table 1) were better at the body representation task, suggesting a relationship between social ability and difficulties representing the human body in 3D or matching bodies from different points of view. These findings are consistent with previous research showing a similar relationship between body representation and social ability in TD adults [Kessler & Wang, 2012] and indicate that social ability in general, beyond an autism diagnosis, may be an important factor in predicting the ability to represent the body from different points of view.

The results of this task also revealed that all children performed significantly better on the meaningless than the meaningful stimuli. These findings contrast with studies showing an advantage for processing meaningful stimuli in TD adults [Bosbach, Knoblich, Reed, Cole, & Prinz, 2006] in which prior knowledge of postures aids recognition. This difference may best be understood in terms of different effects of meaning in children and adults. The stimulus trios were piloted on adult participants and selected so that meaningful and meaningless trios were equally hard for adults. If adults show an advantage for meaningful stimuli [Bosbach, et al., 2006] this selection procedure would give us meaningful trios which are intrinsically harder to match because adults can use their knowledge of the stimulus meaning to overcome the complexity. However, if children are not able to benefit from meaning in the same way as adults, they will find the meaningful stimuli harder, as our results show.

In summary, the ASC children performed similarly to younger VMA matched typical children on both the VPT2 and body representation tasks. This performance suggests that these abilities are in line with their VMA (which was the same as the TD children). On the MR task the ASC children performed better than the TD children, suggesting that MR ability is better than those of a similar VMA. However, it would be inappropriate to suggest that MR performance is superior, due to this group having an overall higher CA. The inclusion of an age-matched control group on the VPT and MR tasks in future research would aid in clarifying the extent to which these skills are delayed or superior in ASC.

Predictors of VPT2 Performance

The design of the current study allows us to test how performance on a variety of tasks relates to VPT abilities. Our regression analyses examine how age, BPVS, MR, body representation, ToM, SAS and SCQ scores relate to VPT2. As BPVS was a consistent predictor across all groups, soaking up effects of age, we do not consider this further. Rather, we discuss how each of the other measures relates to VPT2, beyond the general effect of verbal IQ.

We found that performance on the body posture task predicts VPT2 performance in the TD children but not in the ASC children. This suggests that typical children use a body-related strategy to perform the VPT2 task. The EET strategy previously describes in adults is a strong candidate here [Kessler & Thomson, 2009]. In this approach, the child imagines themselves in the bodily position and orientation of the doll in the VPT2 task, thus drawing on the same body representation skills as the posture matching task. This is consistent with previous research in adults [Kessler & Thomson, 2009; Surtees, et al., 2013b] which suggests that to complete VPT2, TD people represent the body posture and position of the person with the target perspective and then mentally transform their own body to match this viewpoint.

Examining the MR task, we found that scores predicted VPT2 performance in the ASC children but not the TD children. This suggests that children with ASC use a MR strategy to perform VPT2, in which they mentally turn the toy from the doll's point of view to their own to complete the task. This means that the children with ASC are not using the (typical) EET strategy to perform the VPT2 task. Recent research has shown that people with autism may have difficulty with using the self as a reference frame when performing spatial transformations [Pearson, et al., 2014] and may draw on spatial information in perspective taking tasks if it is available to them Langdon and Coltheart [2001].

Overall, the present data are consistent with the claim that there are two possible strategies that can be used to accomplish a VPT2 task—an EET strategy or a MR strategy. Typical children prefer to use the former, while ASC children prefer to use the latter. This implies that in tasks which can be solved using both a social and spatial strategy, people with ASC might be able to compensate for difficulty in social cognition if they have good spatial skills. However, the spatial strategy may be suboptimal—in typical adults, MR strategies tend to be slower and less accurate than performing an EET [Zacks & Tversky, 2005].

We can also consider how performance on the VPT2 task relates to ToM and everyday social skills (measured with the SCQ and SAS). In the previous study [Hamilton, et al. 2009], there was a strong relationship between ToM ability and VPT2 performance in the TD children. This is consistent with earlier findings [Aichhorn, Perner, Kronbichler, Staffen, & Ladurner, 2006; Farrant, Fletcher, & Maybery, 2006; Flavell, 1988]. In the current study, we were only able to examine ToM in the ASC group and found no relationship between ToM and VPT2 ability. This is compatible with the claim that the ASC participants are using a different, spatial strategy to perform the VPT2 task which cannot help them perform the ToM tasks. Note that our study is correlational and does not show whether being more social makes a child better at VPT or having better VPT skills makes a child better at other social skills. However, it is possible that encouraging children with ASC to make use of body information and an EET strategy in VPT tasks could generalize to better use of VPT and ToM in other contexts. A relationship was found between SCQ score and VPT2 ability in the ASC children; participants with better social skills also showed better VPT2 skills. This is consistent with previous studies [Dawson & Fernald, 1987]. This could mean that good use of a spatial strategy helps children with autism in real-world social situations as measured on the SCQ or could reflect individual differences in the use of social strategies among the ASC group tested.

Conclusions

This study tested children with ASC and VMA-matched typical children on VPT, body representation and MR tasks. Results indicate that typical children use an EET to perform VPT, drawing on their good body representation skills. In contrast, the children with autism may use a MR strategy to perform the VPT task, drawing on their strong spatial skills. Our results emphasize the importance of considering different strategies in understanding spatial and social tasks, and may demonstrate compensatory processing in the children with autism.

Acknowledgments

We would like to thank all of the schools, children and parents who took part in this research for giving us their time. Amy Pearson and Lauren Marsh were funded by the University of Nottingham.

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