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Shape constancy in autism: The role of prior knowledge and perspective cues

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Running head: Shape constancy in autism

Key words: Autism, perception, prior knowledge, shape constancy.

### Abstract

Background. Evidence suggests that individuals with autism may not attend to contextual information (conceptual or perceptual) when processing stimuli (Frith 1989; Shah and Frith, 1983).

Method. We investigated the role of prior knowledge and perspective cues when judging the shape of a slanted circle in individuals with and without autism. Individuals adjusted a shape on a computer screen to appear the same as a slanted circle.

Results. Participants in all groups (autistic, moderate learning difficulties, children aged 9 years and adults) exaggerated circularity. Strikingly, however, individuals with autism were unique in exaggerating circularity significantly far less when perspective cues surrounding the slanted circle were eliminated. Prior knowledge that the shape was a slanted circle provoked a strong exaggeration effect in participants without autism, but not in those with autism.

Conclusions. Perhaps classifying the stimulus as a 'circle' was sufficient to provoke a strong exaggeration effect in those without (but not with) autism. In this domain, we show that perception in autism may be less influenced by prior knowledge, and therefore less 'top-down'.

Keywords: Autism, shape constancy, perception, prior knowledge.

Abbreviations: MLD: moderate learning difficulties, DSM: Diagnostic and statistical manual.

## Shape constancy in autism: The role of prior knowledge and perspective cues

### Introduction

Individuals with autism exhibit distinctive visuo-spatial abilities. They perform well in embedded figures and block design tasks (Shah & Frith, 1983, 1993) and in the Rey complex figure task (Ropar & Mitchell, 2001a). Also, it seems that while individuals with autism have difficulty identifying common features in a set of objects, they are relatively good at processing unique features (Plaisted, O’Riordan, & Baron-Cohen, 1998), show enhanced visual search (O’Riordan, Plaisted, Driver & Baron-Cohen, 2001) and might have distinctive processing in size constancy (Hermelin & Pring, 1998).

Further evidence of atypical perception in autism comes from a study by Mottron and Belleville (1993) in which an individual seemed unable to detect the oddity of impossible figures such as the devil’s fork and Penrose triangle. Subsequently, Mottron, Bellville and Menard (1999) reported that individuals with autism had less difficulty than comparison participants in reproducing these impossible figures, again suggesting that they were not perplexed by the oddity of the stimuli.

While impossible figures contain contradicting perspective cues on the orientation of various planes, these contradictions are only evident in a comparison between parts of the figure. Perhaps individuals with autism attended successively to different regions of the stimulus in a piecemeal fashion, with the consequence that they remained oblivious to the perspectival contradictions in the form as a whole (cf, Frith, 1989). Another possibility, though, is that participants with autism experienced “less capture by meaning” (Shah & Frith, 1983). Perhaps those with autism did not compare the stimuli with prior knowledge of the prototypical form that one expects triangles and forks to take. An absence of influence by prior knowledge would liberate them to attend specifically to the stimulus as presented (cf. Ropar & Mitchell, 2001b). In sum, a failure to detect impossibility in the autistic group could be due to less influence by prior knowledge or an inability to integrate facets of the stimulus. Mottron et al (1999) acknowledge these as possible rival explanations for their findings, but their study did not arbitrate between them.

The aim of the present study is to explore the effect of prior knowledge on perception independently of perspective cues using an adaptation of a procedure developed by Thouless (1931a, 1931b, 1932, 1972). His classic study conducted in the early part of the 20<sup>th</sup> Century investigated perceptual distortion associated with shape constancy. He identified a striking phenomenon surrounding participants’ reproductions of a slanted circle: They systematically drew a more circular ellipse relative to the projected image. Thouless concluded that shape constancy exerted its effect by a matter of degree, which caused participants to perceive the ellipse as more circular than actually projected. In other words, whilst presumably the participants encoded the projected shape as an ellipse, the very fact that the projection emanated from a circle contaminated their judgment of how it appeared.

Thouless (1931b) considered two factors that might contribute to this kind of shape constancy. One is the prior knowledge that the stimulus is a circle, and the other is ambient perspective cues. He proceeded to investigate whether prior knowledge alone, was sufficient to provoke exaggeration of circularity. Participants were allowed to see that the object was a circle and then it was presented at a slant in a darkened chamber, such that perspective cues were eliminated. Under this condition,

exaggeration of circularity disappeared, allowing Thouless to conclude that the effect was caused by the ambient perspective cues.

Conversely, Mitchell and Taylor (1999; Taylor & Mitchell, 1997) established that knowledge alone is sufficient for exaggeration of circularity, in studies employing precise measurements and better controls. Initially, participants had an unrestricted view of the stimulus and then viewed it at a slant under test conditions in which perspective cues were eliminated. Here, what participants saw (they saw an ellipse) was in conflict with what they knew of the stimulus (they knew it was a circle). While exaggeration of circularity reliably occurred under this condition in adults and children even as young as 4 years, judgments were in accordance with the projected shape under two control conditions in which there was no conflict between seeing and knowing. In one, participants viewed a slanted circle, but with no access to the stimulus previously, and were thus allowed to believe that it really was an ellipse. In the other condition, participants had unrestricted access previously, but the stimulus was actually an ellipse that was subsequently presented not at a slant under test conditions. In this case, what participants saw under test conditions (they saw an ellipse) was not in conflict with what they knew about the stimulus (they knew it was an ellipse).

The purpose of the current study was to examine differences in the degree of shape constancy between those with and without autism. Participants viewed a stimulus they knew was a slanted circle inside a chamber either that was illuminated, so perspective cues were present, or darkened, in which case only the stimulus itself was visible and perspective cues were absent. Would participants exaggerate circularity when trying to depict the shape? Would their exaggeration be confined to a condition in which perspective cues were present, or would prior knowledge alone be sufficient for exaggeration, even in the absence of perspective cues? Note that the slanted circle itself is devoid of cues as to orientation, and thus it is impossible to distinguish between this and an actual ellipse presented not at a slant in the absence of ambient perspective cues (Pizlo, 1994).

A previous study which is especially pertinent to the current investigation suggests that individuals with autism might be unusually accurate in reproducing a drawing of an ellipse that formed the depicted surface of a rotated cylinder. Mottron and Belleville (1995) found that a drawing savant (E.C.) was substantially more accurate than normal draughtsmen. Although unclear from the report, it seems likely that the draughtsmen systematically exaggerated circularity, while this effect was either far weaker or even absent in E.C. The current investigation goes further by isolating the role of prior knowledge from prior knowledge plus perspective cues. These cues were present in Mottron and Belleville's study, taking the form of the depiction of a rotated cylinder, which were sufficient to indicate that the elliptical surface was a slanted circle. We also extend the investigation by testing a group of individuals with autism who do not have savant status. Finally, our participants were asked to reproduce the shape of a real object rather than a drawing. Mottron and Belleville's study, although very valuable, specifically tells us that a savant is accurate at reproducing drawings of ellipses.

## Method

### Participants

We tested 28 individuals on the autistic spectrum who were all diagnosed by experienced clinicians according to standard criteria (DSM-III or DSM-IV; American Psychiatric Association, 1987, 1994). Three of these individuals were stated as having some features of Asperger's Syndrome, and were being considered for re-

diagnosis. None of the participants were drawing savants. The autistic sample was matched with a group of 20 individuals with moderate learning difficulties (MLD), using the British Picture Vocabulary Scale (Dunn, Dunn, Whetton, & Pintilie, 1982). These individuals had general learning difficulties of mixed aetiology. We specifically excluded any individuals with an autistic related disorder from this sample. Nineteen typically developing children aged 9 years and 14 adults also took part in the study. Table 1 summarises details of participants.

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### Materials

We constructed a wooden chamber (30 x 39cm) with a matte black interior that was completely darkened when the lid was closed (see Figure 1 and also Taylor & Mitchell, 1997). A viewing slot (1x 12.5cm) was cut into the front of the box to allow participants to see inside using both eyes (12 cm from top and positioned centrally in the horizontal plane). A square frame (14x14cm) was mounted centrally on a rod that traversed the interior of the box horizontally, situated 12cm from the top of the box and 31 cm from the viewing slot. The frame housed a sheet of material that could be illuminated. Two masks (13.5 x 13cm) were constructed to place on top of the illuminated material. One had a circular window (7.6 cm diameter) and the other had an elliptical window (3.8 x 7.6cm). Two panels (23.5 x 37 cm) were also constructed and attached to the interior sides of the box for the condition with perspective cues. The panels were patterned with black and white vertical lines (see Figure 1).

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A second box was constructed (28.5 x 42.5cm) to fit over a laptop computer which recorded participants' responses (see Taylor & Mitchell, 1997). The viewing aperture was the same size as in the stimulus box and positioned centrally in the horizontal plane and 3 cm from the top. The interior was matte black. A computer program displayed "starting shapes" of either a white circle or ellipse on a black screen. The starting circle and ellipse had the same length of horizontal axis as the circular and elliptical windows in the masks. The vertical axis of the starting ellipse was 1.6 cm. A key pad connected to the laptop extended outside the box to allow participants to adjust the shape on the computer screen. Stickers identified the two buttons on the key pad which made the shape either more ellipse-like (i.e. ellipse sticker) or more circular (i.e. circle sticker).

### Design

The design of the study included condition (3) and starting shape (2) as within subject factors and group (4) as a between subject factor. The three different conditions were the prior knowledge, perspective plus prior knowledge, and ellipse. In the prior knowledge condition, participants knew apriori that the stimulus was a slanted circle, but the chamber was darkened and only the stimulus was visible therein. In the perspective plus prior knowledge condition, participants viewed a slanted circle inside the illuminated chamber. In the ellipse condition, participants knew there was a non-slanted ellipse inside the darkened chamber. The presentation order of the three conditions alternated between participants. There were two trials for each condition such that each participant had one trial where the starting shape on the

computer screen was a circle and another where the starting shape was an ellipse. The order in presenting starting shapes was counterbalanced between participants.

### Procedure

Initially participants performed a practice trial to ensure they understood how to change the shape using the key pad. Subsequently, each person participated in all three conditions (6 trials in total).

Prior knowledge. Participants initially looked in through the top of the opened box and saw the circular shape oriented at a slant. Then the box was closed and participants looked at the stimulus through the slot, and could see the slanted circle which projected an ellipse with a vertical axis that was 50 percent of the horizontal (this ratio maintained across all 3 conditions, in all 6 trials). The experimenter said, "...inside this box there is a shape (looking in through the top). It's a circle. We can close the box and look inside the peephole to see how it glows. Notice how the circle looks different through the hole." The experimenter then allowed the child to look back and forth through the open top of the box and the peephole. She continued, "Now we are going to close the box and I want you to try and make the shape on the computer screen the same as it looks through the hole." The wording was developed in the light of studies which document the effect of wording on estimations of appearance (e.g. Lichte & Borresen, 1967). When satisfied with the shape they had created their response was recorded by pressing the '+' button on the keypad. A further trial was conducted according to the same procedure, except the starting shape presented on the computer screen changed from a circle to an ellipse or vice versa.

Perspective plus prior knowledge. As in the prior knowledge condition, participants initially looked in through the top of the opened box and saw that the circle was oriented at a slant. Two patterned panels were inserted in the sides of the box in order to provide strong perspective cues. Participants proceeded as in the prior knowledge condition, except the lid of the box was open throughout, allowing ambient perspective cues to remain visible.

Ellipse. Participants initially looked into the opened box and saw that the frame was not oriented at a slant and that it held a mask with an elliptical window. The box was then closed. When participants looked into the viewing slot, they saw an ellipse that was identical in shape and size to that presented in the prior knowledge and perspective plus prior knowledge conditions (but which emanated from a slanted circle in those conditions). Otherwise, the procedure was similar to that in the prior knowledge condition.

### Results

If participants reproduced the projected shape accurately, they would have created an ellipse that was half as tall as it was wide. In that case, the computer would duly record the vertical axis as having 101 pixels (i.e. the horizontal axis was fixed as 202 pixels). This criterion applied to all 6 trials. We performed an ANOVA based on the number of pixels recorded in the vertical axis, including condition (3) and starting shape (2) as within subjects factors and group (4) as a between subjects factor. There was a main effect of condition, which replicates previous research in indicating that participants generated a thinner ellipse in the ellipse condition than in conditions involving slanted circles [ $F(2,160)=116.37$ ,  $p<.001$ ]. There was no main effect associated with participant group, but there was a theoretically uninteresting main effect associated with starting shape: [ $F(1,160)=23.37$ ,  $p<.001$ ]. Perhaps not surprisingly, when participants began with a circular starting shape, then tended to generate a slightly more circular ellipse (mean, 132 pixels) than when they began with

a thin ellipse (mean, 121 pixels). The effect was distributed uniformly across groups and conditions, as indicated by the absence of any interactions involving starting shape ( $F_{(1)}$ ).

There was a theoretically important condition by group interaction [ $F(6, 160)=2.25, p<.05$ ]. In order to clarify the interaction we conducted a series of paired comparisons between conditions, combined over trial, in each group separately. The results of paired  $t$ -tests confirmed that all groups were significantly more likely to exaggerate circularity in the prior knowledge and perspective plus prior knowledge conditions relative to the ellipse condition ( $p<.005$  in all cases). However, individuals with autism were unique in exaggerating circularity to a smaller extent in the prior knowledge than in the perspective plus prior knowledge condition, as indicated in Figure 2:  $t(27)=5.46, p<.001$ . This striking contrast seems to be the basis of the significant interaction reported above.

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 insert Figure 2 here  
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We proceeded to examine whether participants were significantly more likely to exaggerate circularity relative to the projected shape (101 pixels), combined over the two trials in each condition. All groups significantly exaggerated size for the prior knowledge and perspective plus prior knowledge conditions ( $p<.01$  in all cases), but slightly underestimated size in relation to the projected shape in the ellipse condition ( $p<.05$  in all cases).

Finally, we repeated the analyses after excluding 3 participants from the autistic sample who were being considered for a re-diagnosis of Asperger's syndrome. The pattern of results was unchanged, and notably, the interaction between group and condition remained significant.

### Discussion

Participants in all groups exaggerated circularity on the basis of prior knowledge that the stimulus under inspection was a slanted circle. In contrast, participants reproduced an ellipse presented not at a slant closely in accordance with the projected shape in the ellipse condition. In the latter, participants generated a slightly thinner ellipse than appropriate, which might be due to a small error in calibration of the apparatus or to a perceptual distortion of unknown origin.

By far the most interesting finding in the present study, though, surrounds the difference between groups in the effect of prior knowledge. Participants with autism reproduced an ellipse that was closer to the projected shape of a slanted circle in a context where they only had prior knowledge of the actual shape, compared with a context that was suffused with perspective cues. Participants with autism were unique in showing a contrast between the two conditions. Taylor and Mitchell (1997) predicted an effect of this kind in connection with artists, but the prediction gained no support from their data. The striking effect in autism assumes an even greater significance when contrasted with an absence of such an effect in other groups. It suggests the basis of the effect in autism is probably deep seated, and not something that occurs by way of experience or aptitude, at least of the kind normally associated with artistic ability.

Perhaps the difference in judgments between those with and without autism was not due to how the stimulus was inspected and perceived but due to rather trivial differences in the interpretation of the instructions. Evidently, participants in all groups generally understood that they were not simply being asked to generate a somewhat circular ellipse, given that their judgments closely approximated the

projected shape in the ellipse condition. The prior knowledge and perspective plus prior knowledge conditions were special in that the real and projected shapes differed, possibly allowing for ambiguity over which was supposed to be reproduced (see Carlson, 1977; Lichte & Borresen, 1967). Perhaps participants with autism thought they were being asked to reproduce the projected shape, while those without autism thought they were being asked to reproduce the real shape. However, this ‘communication account’ would be at a loss to explain why individuals with autism performed differently between the prior knowledge and perspective plus prior knowledge conditions. The pattern of results is also difficult to explain by suggesting that the groups differed in basic graphic abilities: There is no obvious reason why a difference in drawing accuracy should be manifest in only one of the experimental conditions.

We are left with the interesting possibility that individuals with autism were not so heavily influenced by prior knowledge of the actual shape when reproducing the projection, so long as perspective cues were absent. The current data deviate from those of previous studies in which prior knowledge did not differentially influence the judgments of individuals with autism in perceptual and conceptual tasks. Brian and Bryson (1996) hypothesised that the meaningfulness of the global figure would be an impediment to how swiftly participants without autism (but not with autism) would detect an embedded figure. As expected, this proved to be the case in individuals without autism but surprisingly, the same was also true for individuals with autism. In both groups, prior knowledge of the forms represented by the global shape seemed to hamper their search for the smaller figure embedded therein.

Along similar lines, Pring and Hermelin (1993; also, Ropar and Mitchell, 2001b) predicted that prior knowledge would differentially influence individuals with and without autism in a task requiring them to pair stimuli. In Pring and Hermelin’s study, individuals with autism (savant artists) paired a wine glass with a wine bottle, contrary to the prediction that they would pair the wine glass with a tulip according to the common structural properties of the two stimuli. In Ropar and Mitchell, individuals with autism paired a blue banana with the colour yellow rather than blue. In this case, and again contrary to prediction, individuals with autism based their pairing on prior knowledge of the normal colour of bananas.

In the context of null results in previous studies, our findings that individuals with autism were less influenced by prior knowledge than comparison participants is especially noteworthy. There are a few possible reasons for the discrepancy in results between studies. First, note that the current study does not actually demonstrate an absence of influence by prior knowledge in autism, but an attenuation in effect. The measures used in the current study are probably more sensitive than previous studies in detecting differences by a matter of degree between groups. Second, previous studies were concerned with crystallised or semantic prior knowledge (e.g. stored knowledge about the colour of a banana and what one normally drinks out of wine glasses). Although semantic knowledge was also pertinent to the current study (e.g. prior knowledge of the category of circular things), the interesting contrast between conditions arose from episodic information presented within the trials (e.g. whether the target is a circle oriented at a slant or an ellipse not at a slant). Perhaps this kind of episodic prior knowledge has less impact on individuals with autism (cf, Bowler, Gardiner, Grice & Saavalainen, 2000).

In the perspective plus prior knowledge condition, there are in principle two factors which could have led to exaggeration of circularity. One is the knowledge that the stimulus falls into the class of objects we call ‘circles’. The other is the optic array

which conveys that the target is slanted (cf, Gibson, 1966). This information, which projects 2-dimensionally onto the surface of the retina, would be sufficient to specify the 3-dimensionality of the stimulus, according to Gibson. This allows a shape-constancy process to function even if the participant did not regard the stimulus as belonging to the class of objects known as 'circles'. Our results do not inform us which of these two factors was responsible for the level of exaggeration in participants with autism when performing under the perspective plus prior knowledge condition. Importantly, it does not necessarily follow that the strong exaggeration of circularity in this condition occurred because the perspective cues potentiated participants' classification of the object as a circle.

In contrast, exaggeration of circularity in the prior knowledge condition depends on participants classifying the stimulus as a circle. Because individuals with autism were unique in exaggerating circularity less in the prior knowledge than in the perspective plus prior knowledge condition, it seems that object classification is distinctive in autism, at least with respect to perception. However, we do not know whether this is because classificatory prototypes are different, or whether the activation of these prototypes is different. For example, it might be that the category (and prototype) of 'circle' is ill-defined in autistic cognition, in which case we need to seek an explanation at the semantic level. Alternatively, the category (and prototype) might be normal, but briefly seeing that a stimulus is a circle might be insufficient to strongly activate the appropriate category prototype. In this case, the effect is explicable with reference to differences between individuals with and without autism in the impact of episodic information (cf, Bowler et al, 2000). Either way, it is an important possibility that autistic perception is distinguished by sometimes being less 'top down', or conceptually driven, compared with individuals who do not have autism (cf, Mottron & Burack, 2001).

The finding that individuals with autism exaggerated circularity in the perspective plus prior knowledge condition to the same extent as participants without autism also merits discussion. It seems that so long as the visual display contains depth cues, shape constancy functions normally in autism. However, the results could have been very different: It could have been that individuals with autism were visually able to segregate the projected stimulus from the perspectival context. Given that we know individuals with autism are able to reproduce the shape more faithfully in accordance with its projection in the prior knowledge condition, their greater exaggeration of circularity in the perspective plus prior knowledge condition indicates that, as with comparison participants, they were ineffective at segregating the target stimulus from its visual context. Happe (1996) suggested that individuals with autism are peculiarly capable of visual segregation, and that it confers immunity from the effects of visual illusions. We were unable to replicate attenuated susceptibility to illusions in autism (Ropar & Mitchell, 1999, 2001a), and the current results relating to the perspective plus prior knowledge condition complement our earlier findings but stand at variance with Happe's.

Is the ability to suppress prior knowledge in autism something that is exploited by those who develop savant artistic ability? One of the drawings by Stephen Wiltshire (see Pring & Hermelin, 1993, p1372) is especially pertinent to the topic of the present study. His depiction of the interior dome of the British Library demonstrates, amongst other things, a remarkable talent for reproducing the elliptical projection of a circular feature at the very top of the dome. As mentioned above, though, we might generally expect individuals with autism to show normal exaggeration of circularity in a context such as this, where ambient perspective cues

are present. Mottron and Belleville's (1995) findings do not support this suggestion, but their task required participants to copy a line drawing. Perspective cues might only elicit a normal shape constancy effect in autism in relation to targets that are 3-D rather than 2-D.

In conclusion, it seems that perception in autism may be less influenced by prior knowledge, and therefore less 'top-down' or conceptually driven. This finding has important implications for autism with respect to various kinds of processing which relies on prior knowledge, such as categorizing and generalising. Additionally, our findings emphasize the value of considering that conceptual and perceptual contexts may influence processes independently.

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Table 1. Participant characteristics

Group	CA (yr;mos.)	VMA (yr.mos.)
Autistic (N=28) Mean Sd Range	13;6 2;10 (9;7-18;11)	8;0 3;0 (2;9-15;7)
MLD (N=20) Mean Sd Range	13;6 3;5 (11;0-15;6)	8;5 1;8 (5;11-12;5)
Age 9 (N=19) Mean Sd Range	9;4 0;4 (8;10-9;9)	9;4 1;7 (6;7-12;2)
Adults (N=14) Mean Sd Range	26;5 8;0 (15;10-48;7)	

Figure 1. The chamber for housing the stimulus, in this case with a slanted circle, and the cover for the computer screen (bottom half of Figure).

Figure 2. Shape estimations made on each condition for each group. The ordinate shows the number of pixels in the vertical axis of the reproduced shape (correct judgment = 101 pixels).



