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SHAPE CONSTANCY AND THEORY OF MIND: IS THERE A LINK?

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In three experiments, children aged between 4 and 7 years viewed a circular disc oriented at a slant. The disc was made of luminous material and situated in a darkened chamber. Children of all ages exaggerated the circularity of the disc when they knew that the object was really a

circle (the circle task), and the effect was greatest in the younger members of the sample. Crucially, however, a group of children in Experiment 3 who viewed an identical shape that they knew emanated from an actual ellipse did not exaggerate circularity. In the second experiment, children tackled three standard theory of mind tasks in addition to the circle task mentioned above. A significant correlation emerged (even with age partialled) between the extent of exaggeration made by those who knew that the shape was a circle and ability to pass the standard theory of mind tests. It seems knowledge of reality contaminates judgements of appearance in the circle task. This might be the same bias that features in judgements in theory of mind tasks.

SHAPE CONSTANCY AND THEORY OF MIND: IS THERE A LINK?

When questioned about the shape of a circular disc presented obliquely, it is very likely that a person would say that it is a circle and not an ellipse despite its appearance (Carlson, 1977; Lichte & Borressen, 1967). In other words, people seem attuned to some objective property of shape that transcends the myriad images that might project from the object at different vantage points. Presumably, people apprehend an underlying constancy of shape that is not deemed to be affected by shifts in apparent shape that coincide with changes in viewing position. On the other hand, people do not grossly conflate appearance with reality: If the request was for information about the shape of the object as it appears, then people would have no trouble saying that it looks like an ellipse (Lichte & Borressen, 1967). However, if participants had to estimate the shape, we would expect them to exaggerate the circularity (Thouless, 1931a, 1931b, 1932, 1972). It is as if shape constancy is exerting an effect to the extent that it blinds participants to the actual shape projected onto their retinas.

A Gibsonian (e.g. Gibson, 1966) explanation for this effect is that properties of the visual input are sufficient to specify the object as a slanted circle such that the real shape remains prominent and the apparent shape only incidental. Indeed, the apparent shape may even be difficult to perceive accurately and if there is distortion, it would not be surprising if it was towards the more dominant real shape. Thouless (1932) concluded that this was the sole basis of the effect when he noted that it vanished following his attempt to remove ambient perceptual cues (but see below).

An alternative explanation is that participants' knowledge that the object is a circle might cause them to perceive the apparent ellipse to be more circular than it really is. In previous research we were interested to establish whether knowledge of real shape alone was sufficient to cause the exaggeration (Taylor & Mitchell, 1997). Although Thouless (1932) had concluded that it was not, we had reason to doubt the safety of his conclusion given his primitive methodology. In our study, participants peered into a darkened chamber through a view hole and were able to see an elliptical shape. This was the only visible thing therein, since this alone was made of luminous material. Previously, the participants had been allowed to look into the chamber from above, when the lid was removed, whereupon they saw that there was a slanted circle inside. Participants exaggerated the circularity when asked to replicate the shape on a computer screen, while those tested under a control condition, who had no additional information about the real shape, gave accurate judgments. Crucially, in this research the perceptual cues were eradicated (cf. Pizlo, 1994), so exaggeration of circularity stemmed purely from the knowledge that the thing being inspected was really a circle. It seems the more sensitive method of testing allowed us to identify exaggeration of circularity in a circumstance in which Thouless had failed to detect any effect. The finding demonstrates that perception is informed by our background experiences of the world, along with the resultant assumptions about what it is that we are looking at (e.g. Gregory, 1966).

It seems that although participants were able to dissociate appearance from reality, their knowledge of reality caused a systematic error in their judgments of appearance. This phenomenon as described might have something in common with the classic appearance-reality confusions in children aged 3 and 4 years reported by Flavell, Flavell and Green (1983). They found that young children tend to judge the appearance of an object according to what they know of its real identity. For example, they wrongly judge that a sponge that looks like a rock looks like a sponge specifically when they have established its true identity through touch. Children's knowledge of reality seemed to blind them to the appearance of the object. However, these gross appearance-reality errors were confined to those aged 3 and 4 years. Moreover, Gopnik and Astington (1988) claim that children in their fourth or fifth year experience a radical conceptual shift that equips them with a grasp of representation which allows them to distinguish appearance from reality.

An alternative possibility, though, is that the developmental change is gradual. The apparent stage-like shift might just be an artifact of tests that can either be passed or failed (Mitchell, 1996). A test of that kind is capable of generating data consistent with a stage account but incapable of generating data inconsistent with a stage account. It might be, for example, that young children are captivated by what they assume to be reality to an extent that they are compelled to report this even when asked about appearance. Older individuals might be captivated by their assumption of reality to a lesser extent, and in consequence perform correctly in Flavell et al's (1983) test, but might still be captivated enough to exaggerate circularity in Thouless' (1931a) task. In other words, if we invoke a developmental dimension, then the apparently disparate phenomena reported by Flavell et al and by Thouless may after all be seen to have a great deal in common. The prediction follows that the children who commit realist errors in Flavell et al's task should show greater exaggeration of circularity than children who pass Flavell et al's task.

It is widely believed that the realist errors children make in Flavell et al's (1983) appearance-reality test have the same basis as their realist errors in tests of false belief (e.g. Gopnik & Astington, 1988; Mitchell, 1996; Perner, 1991). While Gopnik and Astington assume that the relation between realist errors across tasks is proof of an impending conceptual shift, Mitchell suggests that the tasks only offer a gross and insensitive measure of how captivating assumed reality is at different ages. The latter account holds that being able to give a correct judgment of false belief might not signal the birth of a new concept, but rather might indicate that a realist bias has faded to a point where the child is no longer destined to answer wrongly.

Characterizing development in this domain as involving a gradual attenuation in bias is different from the conceptual shift view in the sense that realism is no longer seen as a default consequence of lacking a concept, but as a substantive phenomenon. Moreover, it allows for novel predictions to be made. One of these is that young children should stand a better chance of acknowledging false belief if they are protected from the salience of reality, and this is something we have explored previously (Mitchell, 1996; Mitchell & Lacohee, 1991; Mitchell, Robinson, Nye & Isaacs, 1997; Robinson & Mitchell, 1995; Saltmarsh, Mitchell & Robinson, 1995). In those studies, children stood a better chance of acknowledging false belief following manipulations aimed at directing their focus on representation or aimed at diverting them away from their knowledge of reality.

A further assumption arising from the realism account is that when children are old enough to give a correct judgment of belief or appearance, this does not necessarily imply that a realist bias has vanished altogether; it might only be sufficient to resist realist errors on simple theory of mind tests. We therefore predicted that realist errors might be apparent even in adults' judgments of belief under certain circumstances. To find out, we presented adults with a story in which a protagonist fell victim to conflicting information: He saw juice inside a jug initially but later was told that it contained milk. Participants received additional privileged information about whether the utterance was true or false. Adults tended to judge that the protagonist would believe an utterance they knew to be true but disbelieve an utterance they knew to be false (Mitchell, Robinson, Isaacs & Nye, 1996).

In sum, the trouble with tests of false belief and appearance-reality is that they only allow a participant to be defined as having passed or failed, and binary data of this kind are incapable of falsifying the conceptual shift theory. In view of that problem, asking participants to judge the shape of a slanted circle under conditions in which perspective cues are removed could serve as a valuable tool for assessing the extent to which participants are captivated by what they assume to be reality. We predict that such a bias will fade between 3 and 5 years of age, but not vanish altogether (Mitchell, 1994, 1996). We also predict that the magnitude of bias in this circle task (as we shall call it) will correlate with children's realist errors in theory of mind tasks. If the same bias is common to both, then the predicted correlation should emerge. The possibility that the process contributing to errors in theory of mind tasks might also feature in exaggeration of circularity falls beyond the scope of the conceptual shift account. Judging the shape of a slanted circle is not a test of understanding about representation (certainly not in the way intended by those who subscribe to the conceptual shift view), but it could serve as a measure of the degree of a realist bias.

Experiment 1

Method

Participants. In total, we interviewed 194 children, and classified them into 4 age groups according to the class they belonged to. Details are supplied in Table 1.

Table 1 near here

Materials. We constructed a chamber that housed the stimulus disc (see Taylor & Mitchell, 1997, for a diagram). The disc could be viewed within the chamber through an aperture situated in one of the sides measuring 1 cm in diameter. The interior was painted matt black and when all sides were closed it was totally dark. The disc measured 3 cm in diameter and was positioned 31cm from the side with the viewing aperture. The disc was mounted on a rod. Two arbitrary orientations were selected, which gave rise to projective ellipses with minor axes (vertical) of 35 and 55 percent of the major axis (horizontal). An electric light housed inside the box enabled the luminosity of the disc to be recharged between trials.

Children made their judgements of shape by pointing to the matching ellipse in a series of 9 that were printed on a sheet of card. The ellipses all had a major axis of 3 cm and were filled in a uniform black colouring over their entire surface. The minor axis lengths of each successive ellipse in the series increased by a standard 5% of the major axis. The second and sixth ellipses in the sequence accurately matched the projective shapes arising from the slanted disc that was viewed in trials 1 and 2 of the task in which a circle was presented at a slant.

Procedure. Children in each age group participated in each of 2 conditions, called respectively the circle and ellipse conditions. Prior to participating in the circle condition, each child looked through the viewing aperture at a luminous figure of a man that rested directly in front of the luminous disc (which was obscured by a sheet of black card). The child was then asked to select from an array of 5 silhouettes the one which matched the shape that s/he could see inside the box. This allowed the child practice at looking to the correct place inside the box and also at selecting a matching shape from a series of alternatives. Subsequently, children were shown the circular disc inside the box with the sides open, allowing them to see that it was a circle angled at a slant. The box was then closed and children were invited to look into the viewing aperture. The experimenter announced that the disc no longer looked like a circle. Children were asked to look hard at the shape they could see inside the box and then to point to the shape in the series of printed ellipses that they thought looked most like the one in the box. They were then asked, ‘Are you sure that it looks like the one in the box?’ and were prompted to look into the viewing aperture again to check. This process (of referring the child back to the box) continued until the child replied positively. A further trial followed according to the same procedure, but with the disc at a different angle of slant. The two orientations were presented in counterbalanced order between participants.

We wished to establish whether any exaggeration of circularity in the circle task arose from knowledge that the viewed shape was really a circle. If children generally exaggerated the circularity of an ellipse, even a real ellipse viewed squarely, then this would tell us little about visual realism as a developmental phenomenon. Ideally, we would employ the same control used by Taylor and Mitchell (1997), in which participants viewed the circle angled at a slant through the view hole without knowledge that the projective elliptical shape arose from a circle. If exaggeration of circularity was confined to the condition in which participants knew the object was a circle, then this would be strong evidence for knowledge of reality contaminating judgments of appearance. However, pilot testing revealed that such a control condition was not suitable for children. The children were extremely reluctant to look through the view hole unless they had already seen what was inside the box through the open lid. In order to check whether children generally exaggerated the circularity of an ellipse when judging its shape, we devised the ellipse task, as described below.

In the ellipse task, children looked at a printed target ellipse of the same size and shape as the projective shape of the circle when viewed inside the box. The child was then asked to select a matching ellipse from the same array of 9 ellipses that were used in the circle condition. A cardboard screen was placed between the target ellipse and the series of ellipses so that the child could not directly compare them within a single visual scene. The same procedure of prompting was used to establish that children were satisfied with their selection of a matching ellipse. Again there were 2 trials (the target ellipses corresponded to the projective ellipses in the 2 trials in the circle task), the order of which was counterbalanced between participants. Orthogonal to that, the order of participation in the two conditions was also counterbalanced between children.

Results & Discussion

A score was assigned to each child on each of the four trials in which s/he was asked to identify the target shape (whether this was a slanted circle in the box or a printed ellipse) within a series of alternatives. Table 2 shows that in the circle task, children generally exaggerated the circularity of the elliptical shape emanating from a circle presented at a slant. When the projective shape had a minor axis that was 35 percent of the major, on average, children tended to select an ellipse from the array of alternatives that had a minor axis that was 45 percent of the major. When the projective shape had a minor axis that was 55 percent of the major, on average, children tended to select an ellipse from the array that had a minor axis that was 60 percent of the major. In contrast, children seemed to show no systematic bias in the control condition, in which the target shape really did arise from an ellipse. Children’s tendency to exaggerate circularity across the two circle conditions was correlated: $r(190) = .47$, $p<.001$.

Table 2 near here

We computed an analysis of variance on the data, employing the design 4 (Class) X 2 (Order: circle first or ellipse first) X 2 (Condition: circle/ellipse) X 2 (Shape: 35/55) with the last two factors being repeated measures. There was a main effect associated with condition in that generally participants exaggerated the circularity of the ellipse in the circle condition but not in the ellipse condition $F(1, 183)=154$, $p<<.001$. A main effect was also associated with class: $F(3,183) = 5.82$, $p=.001$. These main effects were qualified by a significant interaction between class and condition: $F(3, 183) = 4.77$, $p=.003$. To unpack the interaction, we conducted separate one-way ANOVAs on data arising from the circle condition and the ellipse condition. In both cases, the data were combined from trials involving the two different projective shapes and classified only according to class membership. A significant effect emerged from the circle condition [F (3, 182) = 5.64, p=.001], but not from the ellipse condition [F (3, 182) = .87, p =.46]. We conducted a Newman-Keuls analysis to locate the significance associated with class in the circle data. Children in class 1 did not differ from those in class 2. Those in class 3 did not differ from those in class 4. However, children in classes 3 and 4 were less inclined to exaggerate circularity than children in classes 1 and 2 (p<.05 in all cases). In other words, it seems that the tendency for knowledge of real shape to provoke exaggeration of circularity declined between 5 and 6 years of age.

Returning to the main analysis, there was a theoretically uninteresting main effect associated with the shape of the target ellipse [F(1,183)=21.93, p<.001] which was qualified by a significant interaction with condition (circle versus ellipse): F (1,183) = 30.42. p< .001. Post hoc analyses demonstrated that children exaggerated circularity more in the circle than ellipse trials, and the degree of exaggeration was greatest in the circle condition when the minor axis was 35 percent of the major. This probably arose because there was more scope for exaggeration with this target shape, given that there was a total of seven ellipses more circular than the target in the array of alternatives. In the case of the target that had a minor axis that was 55 percent of the major, there were only three ellipses in the array of alternatives that were more circular than the target shape. Hence, the constraint on the degree of exaggeration differed between target shapes. This was not an issue in the ellipse task owing to the absence of exaggeration under that condition. All other effects to arise from the main analysis were nonsignificant.

We shall now consider a reductive explanation for children’s tendency to exaggerate the circularity of the target shape exclusively in the circle condition. Perhaps some children were tending to select the most circular ellipse from the array simply because they misinterpreted the question to be a request to select the shape that looked most like the real shape of the object that was inside the box (i.e. a circular disc). Accordingly, there would be a bimodal distribution composed of some children judging the shape as they saw it (without exaggeration) and some choosing the most circular ellipse in the array of alternatives. If we wrongly treated this as a unimodal distribution, then we would get the misleading impression of a general bias to exaggerate circularity. To deal with this possibility, we excluded from the analysis any children who selected the most circular ellipse. Fifty eight children selected the most circular ellipse on at least one of the trials (only 3 of these did so on both). The breakdown of exclusions from age-groups 1-4 was 16, 19, 12 and 11, respectively. Even with these exclusions, there was still a significant difference between scores on the circle and ellipse task for the sample overall: $t(132) = 7.04$, $p<.001$. We repeated the analysis for each age group independently and found that the same effect maintained in all cases, though it fell short of significance in the sample of children from class 3: $t(35) = 1.53$, $p=.13$.

Children's realist bias seems to diminish with increasing age but that need not mean that it vanishes altogether. To find out whether it does, we utilized the entire data set once again and examined the estimations of minor axis length made by children in classes 3 (mean age, 6;3) and 4 (mean age 7;1), collapsed over angle of slant of the disc in the circle condition. The analysis confirmed that in both age groups, children exaggerated the circularity of the target shape relative to projective shape: Class 3 -- t (43) = 2.40, p = .02; Class 4 -- t (37) = 3.38, p = .002. Even though 6- and 7-year-old children were less inclined to exaggerate the circularity of a slanted circle than younger children, they still exaggerated to a small but reliable degree.

The results are consistent with the possibility that children's knowledge of real shape caused them to exaggerate the circularity of the disc presented in the circle condition. The effect of this knowledge as a source of bias diminished with increasing age, but it did not vanish altogether; children aged 6 and 7 years also exaggerated the circularity to a small degree, which is not surprising considering that even adults do the same (Reith & Liu, 1995; Taylor & Mitchell, 1997; Thouless, 1931a). Children's exaggeration appears to be linked with their knowledge of real shape, given that they showed no bias to exaggerate circularity when they knew that the target was an ellipse.

It seems that like adults, young children find it difficult to be objective about appearance when they know about the state of reality. The developmental trend suggests that this effect might be greater in the younger members of the sample. Is it possible that this effect is related with children's realist errors in tests of theory of mind?

Experiment 2

In the Introduction, we presented the case for a realist bias in young children's judgments about belief and appearance-reality (the latter is traditionally measured by the rock-sponge test or an equivalent). We are suggesting that children's exaggeration of circularity in the circle task can also be described as stemming from a realist bias. In all these tasks, it seems that the child's knowledge of reality contaminates his/her judgment of appearance or belief. We therefore expect to find a correlation in performance between tasks.

There is an important difference between the circle task and traditional theory of mind tests, however. In the latter, children either give a correct or incorrect judgment, and when they give an incorrect judgment this has led many researchers (e.g. Perner, 1991; Gopnik, 1993) to suppose that they lack the concept necessary for a correct judgment. In other words, the apparent categorical character of children's judgments (you either take account of someone's belief or you do not), seems to lend itself more readily to a deficit explanation than a bias explanation. A peculiarity of those traditional tests is that they present no opportunity for detecting degree of correctness, but this is what is required if we are to determine whether children's difficulty actually stems from a bias. If children had a bias to report reality, they might fail to acknowledge belief in a traditional test and in consequence we could be fooled into thinking that they lacked the concept necessary for giving a correct judgment. In this context, if it turned out that the degree of children's reality bias as measured by the circle test correlated with their performance on traditional theory of mind tests, then the bias hypothesis could seem to offer an important breadth of scope.Method

Participants. The sample consisted of 84 children. We classified them into 3 age groups according to the class they belonged to. Details are supplied in Table 3.

Table 3 near here

Procedure. Each child completed the circle and ellipse tasks, along with the pre-test, as in Experiment 1. Again, the order of presentation of the 2 tasks was counterbalanced. In addition, each child completed three standard theory of mind tasks, commonly employed to assess young children's understanding of (1) the appearance-reality distinction, (2) their own prior false beliefs and (3) the false beliefs of others.

The appearance-reality task involved a candle that looked like an authentic orange. The experimenter allowed the child to confirm that it was not really an orange by allowing the child to handle it, and explained that the object was a candle. The child was then asked the 2 standard appearance-reality questions, based on Flavell et al (1983) : ' What does this look like to your eyes right now ?' and 'What is this really, really ?'

In the test of own false belief, based on Gopnik and Astington (1988), children were shown a Smarties tube and asked 'what do you think is inside this box?'. When they answered with 'Smarties', the experimenter opened the lid to reveal the pencils. The pencils were then returned to the tube, the lid replaced and the experimenter posed the test question: 'When you first saw this box, before we opened it, what did you think was inside?'.

The test of other's false belief involved a simple unexpected transfer narrative accompanied by pictures depicting the main events, adapted from Wimmer and Perner (1983). The pictures and dialogue told of a character called Daisy who, while in her kitchen, sees some biscuits in her mother's shopping basket. Daisy then leaves the room. In her absence Daisy's mother enters and puts the biscuits away in the cupboard. Daisy then returns, upon which her mother tells her that she can have a biscuit. Following this, the experimenter presented the test question: 'Where will Daisy go to look for the biscuits?'.

The order of presentation of the 3 theory of mind tasks was counterbalanced across participants. Half the children completed the circle and ellipse tasks before the 3 theory of mind tasks and half after.

Results & Discussion

Judgments of circularity. As in Experiment 1, children tended to select ellipses that were more circular than the projective shape specifically in the circle condition (Table 4). In the circle task, when the projective shape had a minor axis that was 35 percent of the major, children tended to select an ellipse from the array of alternatives that had a minor axis that was 45 percent of the major. When the projective shape had a minor axis that was 55 percent of the major, children tended to select an ellipse from the array with a minor axis that was 60 percent of the major. In contrast, children showed no systematic bias in the ellipse condition. Children's tendency to exaggerate circularity across the two circle conditions was correlated: $\underline{r}(82)=.55$, $\underline{p}<.01$.

Table 4 near here

We computed an analysis of variance on the data, employing the design 3 (Class) X 2 (Order: circle first or ellipse first) X 2 (Condition: circle/ellipse) X 2 (Shape: 35/55) with the last two factors being repeated measures. There was a main effect associated with condition in that participants exaggerated circularity of the target in the circle condition, but not in the ellipse condition: $\underline{F}(1,78) = 75.79$, $\underline{p}<.001$. There was also a main effect associated with age [$\underline{F}$ (2,78)= 4.87, $\underline{p}<.01$], but the interaction between these two factors fell short of significance: [$\underline{F}$ (2,78)= 2.54, $\underline{p}=.09$]. Despite this, we proceeded with two one-way ANOVAs in order to examine the effect of class specifically in the circle condition. As in the previous experiment, we combined children's judgments for the two target shapes and classified the data only according to age group. The analysis performed on the circle data yielded a significant effect [$\underline{F}(2,79) = 3.97$, $\underline{p}=.02$], while the analysis performed on data from the ellipse condition did not [$\underline{F}(2,79)= 0.34$, $\underline{p}=.71$]. We conducted a Newman-Keuls analysis on the circle data to locate the significance. This revealed that children in classes 1 and 2 exaggerated circularity roughly to the same extent, while children in class 3 exaggerated circularity to a lesser degree relative to children in the two younger classes ($\underline{p}<.05$ in both cases). Nonetheless, children in class 3 still exaggerated the circularity in the circle task, relative to projective shape: $\underline{t}(31)=3.22$, $\underline{p}=.003$. The findings closely resemble those reported in Experiment 1.

The theoretically uninteresting main effect associated with the shape of the target object fell just short of significance [$F(1,78)=3.36$, $p=.07$], but as in the first experiment, shape did interact with condition [$F(1,78)=4.81$, $p=.03$]. Exaggeration occurred exclusively in the circle condition, and the degree of this was greatest when the target shape had a minor axis that was 35 percent of the major. As we said previously, the composition of the array of alternatives, from which children made their judgment, allowed more scope for exaggeration when the projective ellipse was thinner.

Theory of mind. We began by assessing whether children who performed well on one of the tasks also tended to perform well on the other two. Children who succeeded in recalling their own prior false belief also tended to succeed in acknowledging another person's current false belief: χ^2 ($df=1$, $N=84$) = 39.68, $p<.001$. Similarly, children who succeeded in acknowledging their own prior false belief also tended to succeed in judging that the candle was a candle but that it looked like an orange: χ^2 ($df=1$, $N=84$) = 21.00, $p<.001$. Finally, children who succeeded in acknowledging another person's current false belief also tended to succeed on the test of appearance and reality: χ^2 ($df=1$, $N=84$) = 40.61, $p<.001$. We have thus replicated the previously established finding that children who resist a realist error on one task tend to do the same on other tasks (Gopnik & Astington, 1988; Sullivan & Winner, 1991).

In order to examine general age-trends (Table 5), we combined children's scores over the three theory of mind tasks. On each task that children gave a correct judgment, they were awarded a score of 1, and in consequence received a total theory of mind score that ranged from 0 to 3. We computed a one-way ANOVA, classifying the theory of mind composite data according to the class children belonged to: $F(2,80)=13.57$, $p<.001$. We conducted a Newman-Keuls test to locate the significance, which revealed that children in the youngest group had a lower average score relative to members of both older groups ($p<.01$ in both cases). The means from the two older groups did not differ significantly.

Relation between exaggeration of circularity and theory of mind. We combined children's scores on the circle task across the two trials with different projective shapes, which represented a total measure of children’s exaggeration of circularity. We compared data from this composite scale with children’s composite theory of mind score. Means classified by age-group for these two composites are shown in Table 5.

Tables 5 & 6 near here

Table 6 shows a matrix of simple Pearson correlations between theory of mind, exaggeration of circularity and age. The correlation between exaggeration of circularity and theory of mind is not especially great, but when considered in the context of the imperfect correlation between the elements of each composite score, it looks respectable. Figure 1 shows the data points from the two scales plotted in a scattergram. Those who had the highest theory of mind score tended to cluster around the lower part of the exaggeration scale, while those with a theory of mind score of 1 were in the middle and those with a score of zero tended towards the upper part of the exaggeration scale. Few children had a theory of mind score of two, and it is difficult to identify any cluster in the exaggeration scale.

There is an obstacle to simple interpretation of the correlation between theory of mind and exaggeration of circularity. As we have already demonstrated indirectly, performance of theory of mind tests and exaggeration of circularity both correlate (or change) with age. In consequence, the correlation between theory of mind and exaggeration of circularity could be coincidental to their mutual correlation with age. The critical test, then, would examine whether the correlation between theory of mind and exaggeration of circularity survives when age is statistically partialled out: $\underline{r}(81) = -.26$, $\underline{p}<.02$. This statistic confirms that a portion of the variance in theory of mind performance and exaggeration of circularity is shared exclusively and independently of variance accounted for by chronological age. In other words, when exaggeration of circularity decreases, success in theory of mind tests tends to increase in a way that does not simply coincide with changes that take place with age.

Figure 1 near here

It is possible that one component of the theory of mind battery was responsible for the significant correlation between theory of mind composite and exaggeration of circularity. To find out, we examined the relation between exaggeration of circularity and each component of theory of mind independently. It should be the case that children who fail a particular test are more likely to exaggerate circularity than children who pass. The effects arising from the appropriate analyses confirmed that performance of all three theory of mind tests was related with exaggeration of circularity: Own false belief -- $t(55)=2.05$, $p=.05$; Other's false belief -- $t(77)=4.19$, $p<.001$; Appearance-reality -- $t(62)=3.44$, $p=.001$.

Despite the correlation between theory of mind and exaggeration of circularity, the latter still occurs in the older children. While many older children made a correct judgment on all theory of mind tests, most of those same children showed a systematic bias in their exaggeration of circularity. To confirm that this is the case, we examined exaggeration of circularity specifically in children (whatever their age) who made correct judgments on all three theory of mind tests. Of the sample of 84 children, 41 fell into this category. Of the 41, only 12 did not exaggerate circularity. As a group, these 41 children were significantly more likely to exaggerate circularity, as reflected in their composite score, than would be expected by chance: $t(39)=3.04$, $p<.001$.

More generally, it is noteworthy that not only do older children still exaggerate circularity but that there is a developmental lag in the sense that the age-related improvement in judgments seems to occur some time later in the circle task than in the theory of mind tests. Children who commit realist errors in theory of mind tests, and some of those who give correct judgments, are particularly prone to be captured by what they know of reality when judging the shape of a slanted circle. Considering that the age trends do not coincide perfectly, it is perhaps all the more striking that a correlation between the scores of the two should prevail. As far as the reality bias hypothesis is concerned, the imperfect match in developmental trends is not entirely surprising: If there is a general bias to reality, then this might be apparent more readily in some spheres of functioning than in others, and at different ages. For example, Mitchell et al (1996) report a bias to reality in adults in a task that did not reveal the same level of bias in participants in middle childhood. Nonetheless, individual differences in a bias to reality should still be apparent across a range of different tests, and that is what we find.

It is enlightening to consider other studies when evaluating the size of the correlation between exaggeration of circularity and realist errors in tests of theory of mind. Riggs, Peterson, Robinson and Mitchell (1988) found quite a large correlation between children's judgments in an unexpected transfer test of false belief and their ability to reason counterfactually when in the same task they were asked, 'If Mum had not baked a cake, where would the chocolate be?' Whilst the correlation they report is impressive, we cannot be sure to what extent the shared variance was an artefact of the similarity of the methods between tasks. In the current research, the correlations are especially noteworthy given that they arise from methods that are very different from each other. In addition, it is useful to recognize that correlations between measures of theory of mind and non-mentalistic analogues can prove to be elusive. For example, Zaitchik (1990) reported that the developmental trend that arose from children's judgments on her false photo test coincided with the trend in judgments of false belief. However, Perner (1995) showed from a reanalysis of Zaitchik's data that there was actually no correlation between the two measures, in spite of the similar developmental trends.

Experiment 3

One of the most interesting possibilities to arise from the results of the two previous experiments is that knowledge of reality is responsible for exaggeration of circularity in children who are old enough not to make realist errors on theory of mind tests. In one sense, this is not surprising given that Taylor and Mitchell (1997; also, Reith & Dominin, 1997; Reith & Liu, 1995) found such a bias in older children's and even in adults' judgments. In another sense it is a result that would not have been anticipated by Thouless (1932) given the absence of ambient perspective cues in our procedure. Such cues were present in the tasks developed by Reith and colleagues, so the only previous study to suggest that knowledge alone is sufficient to cause exaggeration of circularity is the one by Taylor and Mitchell. The possibility of a bias caused purely by knowledge of reality seemed to deserve further investigation given that background.

Ironically, we might even have predicted tentatively from the study by Mitchell et al (1996) that children aged around 6 and 7 years would not show a realist bias. In that study children did not show realist errors in a modified test that required them to make judgments of others' beliefs, and their judgments proved to be even more accurate than adults who paradoxically did show a realist bias. It might have been that a realist bias faded during middle childhood, only to reappear in adulthood. However, the possibility of a realist bias in 6- and 7-year-olds' exaggeration of circularity seems to speak against this. We felt it worthwhile to conduct a further and better controlled check on whether it is indeed the knowledge of real shape that is responsible for exaggeration of circularity in 6- and 7-year-olds.

Perhaps children were inclined to exaggerate the circularity of the shape presented in the circle task not because knowledge of reality contaminated judgments of appearance, but because of some artifact associated either with the circumstance under which children viewed the slanted circle or with the measurement of children's response. Although it is not obvious why there should be a systematic exaggeration in the circle task, it would not be surprising if children's judgments of the shape inside the box were prone to error. Unlike the ellipse control task, ambient cues of perspective were eliminated in the circle task, which could have hampered the general accuracy of children's judgments. It was essential to eliminate these perceptual cues, of course, in order to reveal whether knowledge of the true shape led to exaggeration of circularity. Inadvertently, however, that may have allowed error of a more general nature to creep into children's judgments.

Another problem surrounded the technique of measurement. Because there was a finite set of ellipses that children could point to, it is possible that they felt none actually matched the shape they could see. This problem could have been further compounded by the fact that the angle of children's line of sight onto the set of ellipses was not controlled. In sum, there was plenty of scope for noise to widen the variance of the data, though it still remains unclear why there should be a systematic bias to exaggerate circularity specifically in the circle task.

In the light of these problems, we introduced a modification to the control condition and also to the recording of children's judgments of shape. The task involving a target ellipse printed on paper was replaced by a task in which the box actually contained an ellipse that was positioned squarely in relation to the line of sight from the viewing aperture. The projective shape of this ellipse was identical to that of the circle when oriented at a slant. Hence, children saw exactly the same shape through the view hole under two conditions. The only difference between them was that under one condition, they knew that the projective shape emanated from a slanted circle, while under another they knew that it emanated from a real ellipse presented squarely. To make their judgment of shape, children looked into a second viewing aperture, through which they could see a computer screen. A circle was displayed on this which the children were able to contract or expand along the vertical axis. Their task was to make the shape on the computer screen look the same as that in the box. There were three main benefits of this recording apparatus: (1) the angle of children's line of sight onto the computer screen was controlled; (2) children could make a judgment of shape that in practice was infinitely adjustable; (3) the recording of children's judgment was done automatically by the computer and stored in its memory for later retrieval following the testing session.

Method

Participants. The sample consisted of 53 children. We classified them into 2 age groups according to the class they belonged to, and details are supplied in Table 7.

Table 7 near here

Procedure. Children completed the circle task, which was identical to that described in

Experiment 1 except for the way in which they made judgments of shape. Additionally, all children completed the new control condition. This was analogous to the circle task in every detail, except that the children saw initially not a slanted circle positioned to the rear of the opened box, but a real ellipse that was oriented squarely in relation to the line of sight from the view hole. We created two ellipses to match the projective shapes of the circle slanted in different orientations. Accordingly, children viewed a total of 4 shapes, two of which had a minor axis that was 35 percent of the major and two of which had minor axes that were 55 percent of the major. The sequence of projective shapes presented to children was counterbalanced. Orthogonal to this, the presentation of the circle task first or the ellipse task first was also fully counterbalanced.

Children made judgments of shape using a laptop computer with an LCD screen. The computer was covered with a hood that had a viewing aperture in it, which controlled the angle at which participants looked onto the screen. The keyboard remained accessible, however, and children were able to use specified keys to expand and contract the vertical axis of a circle that appeared on the screen. The circle measured 3 cm in diameter and was filled in a uniform amber colouring over its entire surface, which very roughly resembled the luminous colour of the disc in the box. The viewing aperture in the computer hood was situated 12cm from the surface of the screen. When the child was satisfied that the shape on the screen matched the shape in the box, the experimenter hit a specified key that made the computer record the data. In a preliminary phase, children practised increasing and decreasing the vertical axis, and all were entirely comfortable with that task.

Children were instructed to make the shape on the computer screen look just like the shape they could see inside the box, using the same prompt described in Experiment 1. They were encouraged to look back and forth between the box and the computer screen until they were satisfied that no further adjustments needed to be made on the computer screen. At this point, the experimenter hit the key to record the child's judgment and the next trial commenced. Generally, the procedure conformed to that described in Taylor and Mitchell (1997).

Results & Discussion

Table 8 shows data consistent with those arising from the two previous experiments, and confirms that children tend to exaggerate the circularity of a shape they know to be projected from a circle, apparently to a greater extent than they exaggerate the circularity of a shape they know to be projected from an ellipse that is presented squarely to the line of sight. To assess these impressions, we submitted the data to analysis of variance, having already established that no effects were associated with the order in which tasks were presented. The design was 2 (class) X 2 (condition: circle or ellipse) X 2 (projective shape: 35 or 55), the last two factors being repeated measures. There was a small main effect associated with class, suggesting that the older children were generally less inclined to exaggerate circularity than the younger: $F(1,51)=5.02$, $p=.03$. There was also a main effect associated with condition, indicating that children exaggerated the circularity more when the projective shape arose from a circle than an ellipse: $F(1,51)=48.13$, $p<.001$. Finally, there was a theoretically uninteresting effect associated with projective shape, indicating that children estimated the minor axis to be greater when the projective ellipse was wide rather than narrow.

Table 8 near here

The main effect associated with age is difficult to interpret because it is unclear whether children are generally less inclined to exaggerate circularity with increasing age, or whether such a trend is confined to the condition in which the projected shape arose from a circle presented at a slant. The interaction effect between age and condition fell short of significance [$F(1,51)=2.64$, $p=.1$], but this is probably an insensitive test. A better method would be to subtract each child's score in the ellipse condition from their score in the circle condition, and examine age trends in the resulting scale. This is something we did, and then submitted the resulting data set to analysis of variance of the design 2 (class) X 2 (projective shape), the last factor being a repeated measure. No significant effects emerged from this analysis, suggesting that specifically the effect of knowledge of reality does not exert a different effect over the age-range we tested. This result is largely consistent with what we found in the two previous experiments.

We proceeded to check whether knowledge of real shape exerted its effect consistently within children. Specifically, would the children who showed this bias for one target shape show it also for the other target shape? We performed the appropriate correlation on data from both ages combined, in which the score on the ellipse task was subtracted from that on the circle task for the two projective shapes: $r(51)=.33$, $p<.02$. It seems fair to describe the correlation as being small but reliable, which is consistent with that reported in the two previous experiments.

Finally, we checked whether children exaggerated the circularity relative to the projective shape of the object. Again, we analysed data which represented children's estimation of shape in the circle condition, with their score subtracted from the ellipse control condition. None of the mean judgments of shape in the ellipse condition indicated underestimation of circularity for both age groups and for both projective shapes. Hence, assessing children's exaggeration of circularity in the circle condition with the scores in the ellipse condition subtracted would serve as a conservative measure of the extent to which knowledge of circularity affects judgments of projective shape. It turned out that children in both age groups were significantly inclined to exaggerate circularity for both projective shapes: Younger children/35 -- $t(26)=5.39$, $p<.0001$; Younger children/55 -- $t(26)4.02$, $p=.0004$; Older children/35 -- $t(23)=3.19$, $p=.004$; Older children/55 -- $t(23)=4.75$, $p=.0001$. In contrast, there was only one instance of significant exaggeration of circularity to be found in the raw scores from the ellipse condition, when we submitted the data to an analogous set of analyses. The younger children exaggerated the circularity of the ellipse which had a minor axis that was 35 percent of the major: $t(26)=2.40$, $p=.02$.

The results provide support for the conclusions drawn by Taylor and Mitchell (1997) but not for those offered by Thouless (1932). The relation between the circle and ellipse conditions in this study was different from that used by Taylor and Mitchell, so it is reassuring to find that exaggeration of circularity is not confined to a particular methodology.

In the previous study, two groups of participants saw identical stimuli through the view hole and differed only in whether they knew that the stimulus arose from a slanted circle. In the present study, participants also saw identical stimuli, and those in one group knew that it arose from a circle while those in another knew that it was an ellipse. In the previous study, participants were allowed to assume that the stimulus was actually an ellipse in the control condition, while in the present study, they knew that it was an ellipse.

General Discussion

Children viewed a luminous circular disc oriented at a slant inside a darkened chamber in the absence of ambient perspective cues. In other words, the disc simply appeared as a glowing ellipse. Children knew that this shape arose from a slanted circle, because they had previously seen it inside the chamber under unrestricted viewing conditions. Children then had to judge the shape by selecting an ellipse from an array of alternatives, or by replicating the shape on a computer screen. In this research the potential source of bias was children’s knowledge that the shape they were viewing was a slanted circle. This knowledge was seldom sufficient for children to judge the shape as a circle, so it seems that they were not conflating appearance with reality in a categorical sense. However, knowledge of true shape seems to have been sufficient to cause children to select an ellipse from the array, or create one on the computer screen, that was more circular than the shape they could actually see.

We cannot tell from our results to what extent knowledge of true shape would bias judgments when the true shape is something other than a circle. Reith and Dominin (1997) report that a similar kind of bias is apparent in middle childhood with square and rectangular stimuli, and Thouless (1931) found the same in adults. Most or perhaps even all stimuli used in these experiments had unique defining labels. It is an open question whether an effect would occur for a shape like an ellipse which is only vaguely defined by the label: There can be thin and fat ellipses. It might be that a bias towards the true shape would not occur for an ellipse presented at a slant. This would follow if the bias arises specifically from participants being able to categorize the true shape with a uniquely defining label such as circle, which defines equality between the vertical and horizontal axes. Since the term ellipse does not possess a defining quality of this kind, recognizing the true shape as an ellipse might not result in participants showing a bias toward true shape in their estimates of appearance.

The exaggeration of circularity appeared in all groups of children, though it diminished with increasing age. The age-trend coincided (albeit imperfectly) with children's resistance to realist errors on traditional tests of theory of mind, and this was not just a function of generally improved performance with maturity: The correlation remained significant even when age was statistically partialled out. Performance on the three theory of mind tests was inter-correlated, and all three also correlated independently with exaggeration of circularity.

The correlation between exaggeration of circularity and judgments on tests of theory of mind is striking when we compare it with those reported previously (e.g. Frye, Zelazo & Palfai, 1995; Riggs et al., 1998; Russell et al, 1991). In the previous research, authors have gone to lengths to stress that the processing involved in comparison tasks is procedurally similar or even identical to that involved in theory of mind tasks. Ours is different, though, because we assume that the procedures for making a judgment of false belief and estimating the shape of an ellipse are substantially different, except that both might be prone to bias by reality. There would have been a similarity if children had made the categorical error of judging the apparent ellipse to look like a perfect circle, but errors of this kind were not predominant. In our research, it thus seems there is a stronger case for arguing that the correlation arises specifically from the bias to reality rather than from other aspects of processing procedures that could be common to the tasks.

______If exaggeration of circularity and errors on theory of mind tests stem at least partly from the same kind of realist bias, then the implications are extremely important. Perhaps a realist bias stands as an impediment to younger children acknowledging the substantive qualities of belief or appearance. It might be that this realist bias gradually diminishes with increasing age, whereupon the child is no longer compelled to report reality when asked about belief or appearance. It would not necessarily mean that the realist bias has vanished, but only that it has attenuated to a point where it no longer dominates the child's response set in a categorical way. If so, then to fully understand the young child's difficulty with the concept of representation (whether belief or appearance), we need to understand the peculiarities of early realism. Specifically, we should no longer regard a realist error in a test of understanding belief or appearance as something that merely happens by default because the child lacks a concept of representation. Whatever the child's understanding, it seems s/he has to contend with a bias to report reality.

Other accounts are different in that they view the reporting of reality as a default that results from a deficit in some other process. The theory theory is the most notable in this respect, where it is said that a child who lacks a concept of belief would be confined to reporting reality. Some interesting implications of that view were outlined by Wimmer and Hartl (1991), who operationalized them into a set of testable predictions in their state change task. However, those results have since been reinterpreted in a way consistent with the reality bias hypothesis (Saltmarsh et al, 1995). A less obvious deficit account is based on mental simulation (e.g. Harris, 1991). Children who are unable to run simulations of other minds would be seen to report reality as a consequence. In other words, a deficiency in simulational abilities would lead to reports of reality by default.

The executive dysfunction hypothesis also characterizes realist errors as secondary to a deficit in another process (e.g. Russell et al, 1991). Young children's supposed lack of executive control leads them to be captured by the salience of reality. So, for example, when questioned on where a protagonist would look for a treat, they are unable to resist pointing to the place where that treat actually is. Similarly, Leslie (e.g. Leslie, 1994; Leslie & Thaiss, 1992) proposes that realist errors stem from an immature selection processor, and implicit in his argument is the contention that when judging about representation, young children are prone to be consumed by what they know of reality. This view is compatible with the one we are advancing, but the emphasis is different. Both accounts posit that children are captivated by the salience of reality, and the realism account sees this as a positive pull towards reality as in a bias, while the executive account sees the same negatively as a default due to lack of executive control.

An account that is similar to that of deficient executive control was put forward by Frye et al (1995). They suggested that children's difficulty acknowledging false belief might reduce to a weakness in a certain form of conditional reasoning that could be measured with a child-based version of the Wisconsin Card Sort. They found that children who showed inflexibility in switching between schemes of reasoning tended also to have difficulty acknowledging representation. This was apparent in a correlation that maintained independently of chronological age. It is not obvious how errors on the card task could be construed as a bias towards reality, and it might be that Frye et al had identified a component in children's difficulty with false belief that stands apart from a realist bias. That said, their account is still a deficit one in the sense that they depict realist errors as a default response made by a child who lacks the requisite reasoning process.

A possible weakness of these deficit accounts is that they do not acknowledge children's difficulty as a direct tendency to report reality. As mentioned above, an exception is Wimmer and Hartl's (1991) thesis, which states that children who are unable to acknowledge belief would be confined to reporting reality. Indeed, the claim is that children's primary conceptual deficit would lead to a secondary deficit in linguistic functioning such that the child would be compelled to interpret a question about belief as being about reality. Hence, the child would interpret "What did you think was inside?" as "What was inside?" This neat prediction turned out to be wrong, however. Saltmarsh et al (1995) presented a deceptive box with a succession of two atypical contents, and asked children aged around 3 years either what they had initially thought was inside or simply what was inside. When asked the latter, nearly all correctly reported the initial content. When asked what they thought was inside, very many wrongly reported the current content. Hence, children do not exhibit the linguistic confusion suggested by Wimmer and Hartl. Moreover, when the elements of state change were included in a test of false belief, children were just as likely to answer correctly as in a test of true belief state change (Saltmarsh & Mitchell, 1998; Saltmarsh et al, 1995).

Instead of viewing children's errors as a default response that results from some kind of failure, perhaps it would be more productive to think of children engaging in a decision-making process. For example, when faced with making a judgment on what a person believes (whether themselves or another person) in a deceptive box test, the possible candidates for belief content are Smarties (the correct option) or pencils (the incorrect option). If children are to answer correctly this can be described as the correct option having a higher cognitive weighting, perhaps because it received loading from the child's recognition that the person had restrictions or distortions on his or her sources of information. It might be that the child gives such a correct judgment when the loading concerned with informational source outweighs the basic loading induced by the salience of reality. These processes might exert influence specifically at the level of explicit decision-making. From this, we predict that if children's performance was measured in a way that did not require them to make a decision, this might reveal early insight into false belief. A finding consistent with the prediction was reported by Clements and Perner (1994), who observed that children's direction of gaze demonstrated sensitivity to the possibility of false belief developmentally prior to children's correct verbal judgments which required them to make an explicit decision.

Development might involve a fading of the lure of reality, and hence reality might come to assume less salience. In this account, the child starts from a point of captivation by reality but is able to overcome this during development. It might partly be the case that developments in executive control and reasoning processes feature in the child's gradual ability to resist reality in tests of false belief, but we urge that these developments at least should be viewed within the context of a basic tendency to be captivated by assumed reality. Our findings suggest that assumed reality becomes intrinsically less alluring given that the degree of reality bias seems to diminish between 3 and 5 years of age, as measured in our shape-judgment task. This diminution does not occur in the form of children's categorical judgments of shape. Apparently, they were comfortable judging that the slanted circle was an ellipse, and by implication they were able to acknowledge the categorical distinction between appearance and reality in this task. From the current data, we cannot tell whether a fading in the salience of reality is sufficient to account for age-related improvements in judgments of belief. Future research might show whether or not variance shared between tests of belief and executive control is actually accounted for by developmental changes in captivation by reality, as measured by our shape-judgment task.

If we do not invoke the lure of assumed reality with respect to tests of theory of mind, then it becomes a struggle to explain difficutly acknowledging own false belief and appearance-reality. In principle, acknowledging one's own prior false belief could be achieved by simple recall; there is no need for any reasoning. Similarly, it is not obvious what reasoning is required to acknowledge the difference between appearance and reality. The child simply needs to hold in mind that the true identity of an object conflicts with current perception; the child is not obliged to navigate through any steps of reasoning to arrive at that understanding. Likewise, it is a puzzle why children fail to acknowledge another person's false belief even when they are told explicitly what the content of that belief is (Wellman & Bartsch, 1988). Moreover, with respect to judging the shape of an ellipse, in our study, reasoning is not only unnecessary but could actually pose an obstacle to correct judgments. Children merely had to make an accurate judgment of a shape as they saw it, whilst suppressing background knowledge of the object's true shape. Conversely, all these phenomena are parsimoniously accounted for by a bias hypothesis, where the specific source of bias is knowledge of reality.

From our account of gradual development, we would expect evidence of early insight into false belief, but also vestigial realism in older children and possibly even adults. We have already discussed evidence relating to precocious acknowledgment of false belief (e.g. Mitchell, 1994, 1996), but add here that resistance to realism might be easier in the domain of perception than in other areas of mentalistic functioning. Even the youngest children acknowledged that the apparent shape was not circular. In some sense, the children were thus able to discriminate appearance from reality. Generally, it is functional for any organism to be attuned to the veridical, but it is also of value to register viewer-specific distortions if the individual is to construct a mental map that will help them to navigate around their environment whilst avoiding collisions with objects. Representing degree of slant is the inverse of representing that an object becomes distorted when viewed obliquely. Representing degree of slant is probably important for understanding how an object is oriented in relation to self such that collisions with protruding features of the object in question can be avoided. Relevant to this, Gopnik, Slaughter and Meltzoff (1994) report that children's ability to acknowledge false belief in relation to shape under perceptual distortion developmentally precedes acknowledgment of false belief in a deceptive box task. They suggest that children's earliest understanding of belief grows from their precocious grasp of perceptual distortions. Our finding that even the youngest children effectively acknowledged the difference between apparent and real shape is consistent with their account.

If realist errors are purely something that happens in an individual who lacks a concept of representation, then we would not expect to find vestigial realism in older individuals. The finding of a residual realist bias in individuals who demonstrably possess the concept of representation (Mitchell et al, 1996) thus elevates the realist bias to the status of a phenomenon in its own right. Hence, there is a potential for knowledge of reality to contaminate judgments of representation in older children and even in adults (Mitchell et al, 1996; Taylor & Mitchell, 1997). We should call this a "coexistence theory" (cf. Subbotsky, 1988) in the sense that a bias to reality coexists with an understanding of the substantive quality of representation.

If a bias towards reality coexists with an understanding of representation, then it probably follows that the bias is functional in some way; its presence would result from benefits it might confer. Suggestions have already been made on how a tendency to report reality might be advantageous when judging beliefs (e.g. Fodor, 1992; Mitchell, 1994, 1996); and as we mentioned above, it is usually of value to any organism to be veridical. The results reported in this study highlight a hitherto unidentified benefit of a realist bias, which is that it might contribute to a process of shape constancy. It seems that perception of shape is likely to be driven by background knowledge of what the thing under inspection actually is (e.g. Gregory, 1966). Although this might lead to perceptual distortions in some instances, as reported in these studies, they might be outweighed by the benefits of a secure hold on the underlying physical invariants of the object under inspection.

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Table 1. Details of age-range and mean age (in months), sex ratio and numbers in each of the four age groups that participated in Experiment 1.

Class	n	age range	mean age	females (n)	males (n)
1	40	42-58	49	19	21
2	52	54-65	58	23	29
3	48	67-84	75	24	24
4	51	79-87	83	25	26

Table 2. Children's exaggeration of circularity of the target shape in Experiment 1 measured in 5 percent increments (minor axis relative to major). A score of 1 indicates selection of an ellipse that had a minor axis that was 5 percent greater in its minor axis length than was the case in the target shape.

	Box					Paper				
	Class					Class				
Target	1	2	3	4	Mean	1	2	3	4	Mean
1 (35)	1.98	2.71	1.40	1.53	1.91	-.05	-.14	-.17	-.20	-.14
2 (55)	1.68	1.39	.33	.73	1.00	.05	-.14	-.15	-.02	-.07

Table 3. Details of age-range and mean age (in months), sex ratio and numbers in each of the three age groups that participated in Experiment 2.

Class	n	age-range	mean age	females (n)	Males (n)
1	30	43-54	49	16	14
2	26	55-66	61	18	8
3	28	68-79	73	15	13

Table 4. Children's exaggeration of circularity of the target shape in Experiment 2 measured in 5 percent increments (minor axis relative to major). A score of 1 indicates selection of an ellipse that had a minor axis that was 5 percent greater in its minor axis length than was the case in the target shape.

	Box				Paper			
	Class				Class			
Target	1	2	3	Mean	1	2	3	Mean
1 (35)	2.37	2.08	1.07	1.85	.07	-.19	-.36	-.16
2 (55)	1.80	1.50	.71	1.35	-.23	-.12	-.11	-.16

Table 5. The mean composite scores for exaggeration of circularity (box) and theory of mind (tom), classified by age group (class) in Experiment 2.

Class	tom composite	box composite
1	0.93	4.17
2	1.92	3.58
3	2.46	1.79

Table 6. Correlation matrix showing the interrelatedness between theory of mind (tom), exaggeration of circularity (box) and age. In all cases, the correlations are significant at $p<.01$ or better, with 82 df.

	Box	Age
Tom	-.36	.47
Box		-.30

Table 7. Details of age-range and mean age (in months), sex ratio and numbers in each of the two age groups that participated in Experiment 3.

Class	n	age-range	mean age	females (n)	Males (n)
1	28	71-82	75	10	18
2	25	83-93	88	13	12

Table 8. Estimations of circularity of the target shape in Experiment 3, showing children's judgments of the ratio of minor axis length relative to major, expressed as a percentage.

	Box Class			Ellipse Class		
Target	1	2	Mean	1	2	Mean
1 (35)	53	43	48	40	36	38
2 (55)	68	65	67	56	57	56

Figure 1. The scattergram shows the negative relation between exaggeration of circularity and correct judgments in theory of mind tests in Experiment 2.