Children's understanding of ambiguous figures: Which cognitive developments are necessary to experience reversal?

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ABSTRACT

In two experiments involving 138 3- to- 5-year-olds we examined the claim that a complex understanding of ambiguity is required to experience reversal of ambiguous stimuli (Gopnik & Rosati, 2001). In Experiment 1 a novel Production task measured the ability to acknowledge both interpretations of ambiguous figures. This was as easy as and significantly correlated with a False Belief task, and easier than a Droodle task. We replicated this finding in Experiment 2, and also found that perceiving reversal of ambiguous figures was harder than either the False Belief or Production tasks. In contrast to previous findings, the Reversal and Droodle tasks were not specifically related. We conclude that children only attempt reversal once they can understand the representational relationship between the figure and its two interpretations. The process resulting in reversal however is hard, probably requiring additional developments in executive functioning and imagery abilities.

INTRODUCTION

This paper investigates at what age children are able to reverse ambiguous figures, and what conceptual abilities are necessary for this ability. Ambiguous figures are pictures which have two different interpretations such as the duck-rabbit (Jastrow, 1900), man-mouse (Bugelski & Alampay, 1961), and vase-faces (Rubin, 2000) (see Figure 1). When informed adults view these figures they tend to experience them reversing from one interpretation to the other. Research by Rock and colleagues suggests that for this to happen, adults must know that the figure is ambiguous and what the interpretations are (Girgus, Rock, & Egatz, 1977; Rock & Mitchener, 1992; Rock, Hall, & Davis, 1994). This implies that reversal is a top-down active process. Perceivers must have a conceptual framework capable of representing that figures can have more than one interpretation, and the abilities necessary to bring about reversal.

However, some adults do experience reversals without being informed of the ambiguity. This might be because they have prior experience with ambiguous figures. Because young children are unlikely to have had such experience, Rock, Gopnik, & Hall (1994; Gopnik & Rosati, 2001) examined spontaneous reversal in preschoolers. When uninformed of the ambiguity, and told to look at a figure for 60 seconds, no child ever reported reversal. These findings support the idea that in order to achieve reversal of an ambiguous figure, the viewer must be aware of the ambiguity.

There was also a developmental effect: even after the ambiguity had been clearly demonstrated to them, informed younger children were particularly unlikely to reverse. This suggests that either the necessary conceptual framework or the ability to bring about reversal arises during the preschool period. The aim of this paper is to examine these possibilities.

Gopnik & Rosati (2001) repeated the reversal procedure, adding a false belief task (Experiment 1) and a 'Droodle' task (Experiment 2). The False Belief task tests for children's understanding of other people's beliefs, which contrast with the child's. It is generally accepted that success on the False Belief task demonstrates that children are able to represent the relationship between beliefs and the state of the world the beliefs are about. Understanding that an ambiguous figure can represent two distinct objects also requires children to be able to represent the representational relationship between the figure and the two interpretations. One therefore might expect an association between the two tasks. Gopnik & Rosati (Expt. 1) found no correlation between the tasks, and the Reversal task was considerably harder than the False Belief task.

The Droodle task requires children to report that a person only seeing a small unidentifiable portion of a stimulus will not know what it is (Taylor, 1988; Perner & Davies, 1991). It can therefore be seen as assessing understanding of the effect that an ambiguous stimulus has on the mental state of a viewer. In the Droodle task, children are shown a small unidentifiable portion of a picture, then shown the full picture. They are then asked whether another person who only saw the small portion would know what the full picture was (Taylor, 1988; Perner & Davies, 1991). The stimulus is ambiguous in the sense that it could plausibly be part of more than one picture. The task assesses children’s understanding of the effect of this ambiguity on the mental state of the viewer. Typically children up until the age of five years wrongly judge that a viewer would know what the full picture was. Gopnik & Rosati found that performance on the Droodle task correlated very well with performance on the Reversal task ($\phi = 0.86$, $p < 0.0001$) and performances hardly differed. Their tentative conclusion was that reversal requires an abstract and complex understanding of ambiguity. They did not provide any more detailed explanation of what this understanding of ambiguity might entail.

If correct, this finding would indicate that the critical development is in the conceptual prerequisites of reversal, rather than the ability to bring it about. It would also indicate what the conceptual prerequisites are: whatever gives rise to success on the Droodle task. However, this finding is surprising for several reasons. Both the Reversal and Droodle tasks require children to understand that a stimulus can have two interpretations, and is therefore ambiguous. However, each has additional requirements that the other does not. The Droodle task also requires children to understand the effect of this ambiguity on the knowledge state of another person; the Reversal task does not. The Reversal task requires children to perform some kind of mental action; the Droodle task does not. Neither additional requirement seems trivial, so a strong association between the tasks would not be expected.

Because Gopnik & Rosati's findings were surprising, unexpected, and came from a small sample of only 28 participants, in pilot work for the present paper we compared performance on the Reversal, False Belief & Droodle tasks in a sample of 62 3- to 5-year-olds (the methods of all 3 tasks were as used in the experiments reported below). We found that the Reversal and Droodle tasks were of similar difficulty, but were only very weakly related ($r = .26$, $p < .05$). The finding of a relatively weak relationship between the two tasks is consistent with our task analysis.

It therefore remains plausible that the conceptual prerequisites of reversal arise earlier than success on the Reversal or Droodle tasks. If reversal is a top-down process, children must first be able to understand that one figure can have two interpretations. This poses a representational puzzle similar to that posed by homonymy. Homonyms are words with two unrelated meanings, such as <u>bat</u> (sports equipment) and <u>bat</u> (flying animal). Both ambiguous figures and homonyms are tokens in a representational medium – pictorial or linguistic – which can represent different things depending on context. Understanding this requires children to represent the relationship between the representational medium and the situation referred to. False belief and synonymy also require children to do this: synonymy, because one situation can be referred to by two different words, and false belief because one situation can be represented by different beliefs (some of which may be false).

Children pass tasks assessing their understanding of homonymy, synonymy and false belief at roughly the age of four years, and performances on these tasks have been found to be consistently intercorrelated (Doherty & Perner, 1998; Doherty, 2000; Perner, Stummer, Sprung & Doherty, 2002). We would therefore expect children to pass a task requiring them to acknowledge the two interpretations of an ambiguous figure at the same age, and for their performance to correlate with performances on any of these other tasks.

Experiment 1 investigates whether children are able to acknowledge both interpretations of ambiguous stimuli at a younger age than they have been found to reverse. In order to do this we adapted the "say something different" (SSD) task, previously used to assess understanding of synonymy (e.g. Doherty & Perner, 1998; Perner et al., 2002) for use with ambiguous figures. Early ability to acknowledge both interpretations, and a continued lack of association between the Reversal and Droodle tasks would support the idea that the basic conceptual development involved is the ability to understand that one stimulus can have two interpretations. Possible additional cognitive developments, such as developments in executive function and imagery might also be involved; we consider these in the General Discussion.

In our novel SSD task the experimenter showed children an ambiguous figure and provided one interpretation, e.g. "rabbit". The child's task was to name the alternative interpretation ("duck"). After some intervening trials, the experimenter showed the same figure, this time providing the other interpretation, e.g. "duck". Again the child had to name the alternative interpretation ("rabbit"). Children were scored as successful on that item if they could supply the alternative interpretation on both occasions. This criterion was necessary since children would be successful half the time by providing their favored interpretation regardless of what the experimenter said.

EXPERIMENT 1

Method

Participants

Seventy three children (39 girls) from five preschools in Stirling, Scotland took part. Three additional children did not complete the experiment. Children comprised four groups as follows:

3-year-olds:	18 children from 2;10 to 3;6, mean age 3;3, SD = 2.5 months.
3½-year-olds:	19 children from 3;7 to 4;1, mean age 3;10, SD = 2 months.
4-year-olds:	19 children from 4;3 to 4;10, mean age 4;7, SD = 2.5 months.
5-year-olds:	17 children from 4;11 to 5;6, mean age 5;2, SD = 2.5 months.

Design

Each child received all four tasks: the Production ambiguous figure task, the False Belief and Droodle tasks, and an additional ambiguous figure task we will not discuss here. Testing comprised two sessions, one with the False Belief and Production tasks and one with the Droodle and the other ambiguous figure tasks. Order of the two sessions and of the two tasks within each session was counterbalanced

Materials

Production task

The ambiguous figures were three line drawings depicting a duck/rabbit, a vase/faces and a man/mouse (see Figure 1). Each was drawn in pencil on A4 (29.5 x 21 cm) paper. For each ambiguous figure there were two disambiguating context drawings. For example, for the duck/rabbit the two drawings were of a duck’s body on a lake with other ducks in the background, and a rabbit’s body, complete with a carrot. These were also on A4 sheets with holes cut to accommodate the ambiguous stimulus, in this case the duck's/rabbit's head. The other disambiguating context drawings are also shown in Figure 1.

Droodle

The Droodle task involved two A4 pencil drawings of a birthday cake and of a giraffe. A second piece of paper with a 3 cm square hole could be laid over these drawings. With only this small portion of the drawing visible it was impossible to tell what was depicted. A hand puppet served as research assistant.

False Belief

The False Belief task involved two Playpeople dolls (5 cm), a marble, an opaque jar (5 cm high x 2.5 cm wide) and a box (3 cm high x 4 cm wide).

Procedure

Children were tested individually in a quiet part of the classroom. Each session took approximately ten minutes.

Ambiguous figures disambiguation phase

This phase took place before the Production task. The child was presented with one of the ambiguous stimuli, for example the duck/rabbit. The experimenter said: "I have a funny picture for you, shall we have a look? Now this is a picture which can be two different things. What do you think this is? [Child answers, e.g. rabbit.] Yes, you are right, it's a rabbit." The experimenter then put the rabbit's body onto the stimulus to disambiguate it, reinforcing the child's interpretation. The child was asked to point out the rabbit's ears. Then the experimenter said "But look it can be something else too. [puts on the body of the duck.] What is it now? … Yes you are right, it's a duck!" Again the child was asked to point out the duck's mouth to ensure that s/he was genuinely perceiving this alternative. The experimenter finally reminded the child of the two alternatives: "Now this is very funny. This picture can change back and forth from a rabbit [briefly adds the rabbit’s body] to a duck [briefly adds the duck’s body]” and then with appropriate swapping of the disambiguating context drawings and brief pauses to allow the child to look at the figure, “or from a duck to a rabbit. But it might just stay a rabbit or it might just stay a duck”.

Children usually referred to the vase as a cup. The experimenter subsequently referred to it in the same way.

Production task

The experimenter first told the child “Remember, all these pictures can be two different things. Now I am going to say one thing and I want you to say the other thing, ok?”. She then showed the child the first picture, the duck/rabbit, without either of the disambiguating context drawings and said, “This is a rabbit. What else can it be?”

If the child repeated the experimenter, she said “But I’ve already said that it’s a rabbit. What else can it be?”. If the child did not provide the correct answer after a reasonable pause, the experimenter said, “I know! It can be a duck, can’t it?”.

This procedure was repeated with the vase/faces and man/mouse figures, with the experimenter identifying them as glass and man. Then each trial was repeated in the same order, with the experimenter identifying the objects with the other interpretation: duck, faces, mouse. Children were scored correct on an ambiguous figure if they were able to supply the opposite interpretation on both trials. Thus children were able to score from 0 to 3.

False Belief task

For this test a short story was acted out with the two dolls, marble, jar and box. In the story Sally, places a marble in the box and exits. In her absence Tony moves the marble to the jar and also leaves. Sally returns and children are asked the following questions:

Belief Question: Where will she look first for her marble?

Reality Question: Where is the marble really?

Memory Question: Where did Sally put the marble in the beginning?

Droodle task

Self experience question

One of the drawings was selected and the piece of paper with a 3 cm square hole laid over it so that only a small unidentifiable portion of the drawing was visible. Children were shown this and asked what the drawing was. Whether or not they had a guess, the experimenter said "Shall we have a look what it is?" and removed the cover to reveal the object. The cover was then replaced. The experimenter brought a puppet out of her bag and said "Puppet has never seen this picture before. If he comes in and sees just this bit, does he know that this is a giraffe/birthday cake?".

Full information control question

This was similar to the self experience test, except that the drawing was fully visible from the start. Children were asked what it was, and then without concealing the drawing, Puppet was brought out and the experimenter said "Puppet has never seen this picture before. If he comes in and sees this, does he know that this is a birthday cake/giraffe?".

To pass the Droodle task, children had to answer "no" to the self experience question and "yes" to the full information control question. The self experience task was always presented first, and which picture was used for which task was counterbalanced between children.

Results

False Belief task

Children's performance on the False Belief question was typical of this age range, with a majority of 3-year-olds failing and a majority of older children passing (see Table 1). This improvement is significant: Kruskall-Wallis $\chi^2 = 19.3$, df = 3, $p < 0.001$. The only significant difference between adjacent age groups' performances is between those of 3½-year-olds and 4-year-olds, Fisher's Exact, $p = 0.038$.

Droodle task

Children's performance on the Droodle Task was also typical: most 3- and 4-year-olds failed; a majority of 5-year-olds passed. This improvement is also significant, Kruskall-Wallis $\chi^2 = 19.8$, df = 3, $p < 0.001$. The only significant difference between adjacent age groups' performances is between those of 4-year-olds and 5-year-olds, Fisher's Exact, $p = 0.007$.

Production

Table 2 shows children's performance in the Production Task. Most of the 3-year-olds managed to produce no pairs of interpretations or only 1, whereas most 4-year-olds produced all three pairs. This age improvement is significant, $F(3, 69) = 13.2$, $p < 0.001$. Contrast analysis shows that the only significant difference between adjacent groups' performances is between those of the 3½-year-olds and the 4-year-olds, $t(69) = 3.07$, $p = 0.003$. In most cases when children failed to produce a pair they produced one single item. There were 6 cases where neither rabbit nor duck was produced, 6 cases where neither cup nor faces was produced, and 4 cases where neither man nor mouse was produced. Only one child failed to produce either interpretation on all three trials.

Comparison of tasks

Table 3a shows intercorrelations between age and performance on the Production, False Belief, and Droodle tasks[1]. Table 3b shows intercorrelations between these tasks when age is partialled out. Performances on all tasks are strongly related to age. Although all tasks are correlated, only the correlation between performances on the Production and False Belief tasks remain significant when age is partialled out.

In order to compare all tasks, children were scored as passing the Production task if they produced at least 2 out of 3 pairs of interpretations. This strikes a balance between excessively strict (3 out of 3 trials correct) which would punish minor lapses in attention, and excessively lenient (1 out of 3 trials correct) which might allow some success through random factors. The Droodle task is harder than the False Belief and Production tasks (McNemar, binomial, both ps < 0.001), which are of equal difficulty.

Discussion

The Production task assesses the ability to acknowledge that there are two interpretations of an ambiguous figure. The results show that this ability develops rapidly around the age of 4-years and is linked to the ability to understand belief. It is considerably easier than the ability to pass the Droodle task. This is consistent with the hypothesis, introduced above, that children are able to conceive of a stimulus as having more than one interpretation from the age of roughly four, and this understanding has a common basis with understanding of belief. It is this understanding, we suggest, that allows children to <u>attempt</u> reversal. In the following experiment we compare performance on the Production task with performance on the Reversal task.

EXPERIMENT 2

Participants

Sixty-five children (36 girls) from a working class and middle class primary school in Stirling, Scotland took part. Children comprised three groups as follows:

3-year-olds: 21 children from 3;4 to 4;4, mean age 3;10, SD = 4 months.

4-year-olds: 23 children from 4;5 to 4;11, mean age 4;8, SD = 2 months.

5-year-olds: 21 children from 5;0 to 5;9, mean age 5;4, SD = 2.5 months.

Design

Each child was tested on four tasks: False belief, Droodle, Production and the Reversal task. Half the children had a Disambiguation phase based on Rock, Gopnik, & Hall's original task, and half had the version used in Experiment 1. Children either received the Production task first and the Reversal task last or vice versa. The False Belief and Droodle tasks were administered second and third, counterbalanced.

Procedure

Reversal task

Disambiguation phase

Version 1 of the Reversal task included the Disambiguation phase used in Experiment 1. Version 2 had the disambiguation phase used by Rock et al. (1994). The figures were disambiguated by analogy, showing a disambiguated picture of each interpretation, rather than by adding appropriate surrounding context. Otherwise the two versions were identical.

Test Phase

The experimenter said "Now I want you to look at this picture. Remember it might change or it might not. You tell me if it changes or not, and see if you can keep looking at the picture". As well as asking children to report any changes in interpretation, the experimenter also asked, "what do you see", after 5, 30 and 60 seconds. Children who reported a change in interpretation of the ambiguous figure at any point in the 60 second period were coded as reversers; children who did not report any change were coded as non-reversers.

Production task

The stimulus set in the Production task was altered to prevent carry-over effects between it and the Reversal task. Whichever of the three stimuli was used in the Reversal task was replaced with the Eskimo-Indian ambiguous figure (Ernst, 1986; see Figure 1d). Otherwise the counterbalancing was as before.

Results

False Belief and Droodle tasks

Performances on the False Belief and Droodle tasks were again typical (see Table 4). Most 3-year-olds failed the False Belief task and most older children passed. This improvement is significant: Kruskall-Wallis $\chi^2 = 11.6$, $p = 0.003$. Differences between adjacent groups' performances were only marginally significant (Fisher's exact, ps < 0.07). Most 5-year-olds passed the Droodle task and most younger children failed. This improvement is significant: Kruskall-Wallis $\chi^2 = 13.1$, $p = 0.001$. The only significant difference between adjacent groups' performances is between those of 3- and 4-year-olds, Fisher's Exact $p = 0.007$

Production

As before, most 3-year-olds produced no pairs of interpretations or only one, and most older children produced at least two pairs. This age improvement is significant, $F(2, 62) = 9.84$, $p < 0.001$. Contrast analysis shows significant differences between both the 3- and 4-year-olds' and the 4- and 5-year-olds' performances ($t(62) = 2.47$, $p = 0.016$ and $t(6) = 2.06$, $p = 0.044$, respectively).

Reversal tasks

Performance on the two versions of the reversal task could not have been closer: 34% of children reversed on Version 1 and 33% reversed on Version 2. The two tasks were combined into a single reversal measure. Most 3- and 4-year-olds did not report reversal, whereas most 5-year-olds did. This age improvement is significant, Kruskall-Wallis $\chi^2 = 7.64$, $p = 0.022$. The only significant difference between adjacent groups' performances is between those of 4- and 5-year-olds, Fisher's Exact $p = 0.037$.

Comparison of tasks

Table 5a shows intercorrelations between age and performance on the four tasks; Table 5b shows intercorrelations when age is partialled out. Performances on all tasks are positively correlated with age. Most other tasks are intercorrelated; the strongest correlations are between performance on the Production task and performances on both the False Belief and Droodle tasks, $r = 0.43$ and $r = 0.44$, respectively, $ps < 0.001$. These correlations remain significant after age is partialled out, although the correlation between performances on the False Belief and Production tasks is only marginally significant, $p = 0.056$. Performances on the Droodle and Reversal tasks were only modestly correlated, $r = .31$, $p < 0.05$, and this correlation did not remain significant after age had been partialled out, $r = 0.18$.

As in Experiment 1, children were considered to pass the Production task if they produced at least 2 out of 3 interpretations. The Production and False Belief tasks did not differ in difficulty and both were easier then either the Reversal or Droodle tasks (McNemar, binomial, $ps < 0.001$). The Reversal and Droodle tasks were of equal difficulty.

Discussion

The results of Experiment 2 are clear. The Production task was again of similar difficulty to the False Belief task. Both were easier than either the Droodle or Reversal task. The Droodle and Reversal tasks were of similar difficulty, but not strongly related. After partialling out age, the Reversal task did not correlate with any other task, including the Production task. The Production task however correlated with both the False Belief and Droodle task (although the correlation with False Belief remained only marginally significant when age was partialled out).

The lack of correlation between the Reversal and Production tasks, although superficially surprising, is consistent with our argument: Reversal does not occur until children pass the False Belief and Production tasks, suggesting that these tasks mark a prerequisite. However, Reversal does not correlate with either of them, suggesting that the prerequisite is not required for reversal as such, but for a quite different process that will result in reversal.

GENERAL DISCUSSION

We failed to find the remarkably strong correlation between the Reversal and Droodle tasks found by Gopnik & Rosati (2001). The two tasks were of similar difficulty, but were only weakly related. Our findings therefore do not support the idea that the ability to perceive reversal is based on an abstract and complex understanding of ambiguity.

However, the understanding that there can be two interpretations of an ambiguous figure seems to arise about a year earlier than the ability to perceive reversal. We designed the novel Production task to elicit this understanding. As hypothesised, this task was of similar difficulty to the False Belief task, and performances on the two tasks were substantially and significantly correlated. The correlations remained significant after age was partialled out, if only marginally so in Experiment 2, suggesting that despite the superficial differences in the tasks, both involve a common understanding.

There are potential counter-explanations for our findings. The Production task of course requires the ability to recall the alternative interpretation of a figure. Our assumption is that without the ability to conceive of their even being an alternative interpretation children will not even attempt to recall it. False positives would therefore be unlikely. The danger of false negatives is more serious: children might understand that there can be an alternative percept, but be unable to recall what it is. Effective recall also involves the ability to suppress the currently perceived alternative, so executive function deficits might also account for poor performance.

We cannot discount these possibility on the basis of present evidence, but the close analogy between the Production task and the "say something different" tasks used in previous research suggests that these potential executive function or memory deficits are not particularly problematic in this kind of task with this age group. Understanding of homonymy, synonymy, and hierarchically related terms such as dog and animal, have all been assessed using production SSD tasks. These tasks pose similar recall and executive difficulties to the ambiguous figures Production task. For example, in the Synonym Production task, children are provided with one word, truck, and required to state its synonym, lorry. This requires recall of lorry and suppression of truck.

However, these tasks have also been administered in judgement versions. Children are required to judge the production attempts of another. In the synonym task, for example, a puppet might produce the same word as the child (incorrect), a misnomer, or a synonym (correct). Children have to judge whether that was what Puppet should have said. Recall and inhibition demands are therefore kept to a minimum, since both alternatives are provided almost simultaneously by the experimenter. Despite posing different executive difficulties, the judgement and production versions of these SSD tasks are of equivalent difficulty, and both types of task substantially correlate with the false belief task (Doherty, 2000; Doherty & Perner, 1998; Perner et al., 2002). Performance on our ambiguous figures Production task develops in a very similar way to performance on the other SSD tasks, and shows a similar association with false belief understanding. It therefore seems reasonable to conclude it measures a similar competence, and therefore is unlikely to be substantially affected by poor recall or executive functioning.

Regardless of its cause, the present study nevertheless highlights a critical prerequisite for reversal. Until the age of roughly four years, children cannot report both interpretations of an ambiguous figure. At this age, they become able to do so; this development coincides with the ability to pass the false belief task, and is specifically associated with it. What remains to be explained is why children do not experience reversal until roughly a year later.

The visual search hypothesis suggests that one simply needs to look at the appropriate part of the figure for it to reverse. If children understand that there can be an alternative percept, they should be motivated to search for it. It is not clear why search should be difficult, and it does not offer a ready role for development. Rock et al.'s imagination hypothesis, on the other hand, suggests that one has to impose a mental image of the alternative interpretation onto the stimulus in order to get it to reverse. This plausibly requires a high degree of cognitive control, or executive function. Children would have to suppress or inhibit the currently experienced interpretation. There is considerable evidence that this kind of inhibitory ability is still developing in the preschool period (Russell, Mauthner, Sharpe, & Tidswell, 1991; Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996; Carlson & Moses, 2001).

Children would also need visual imagery abilities. There is evidence that at least some of these abilities are also developing in the preschool period (Kosslyn, Margolis, Barrett, Goldknopf, & Daly, 1990). There is also an implied link with the development of theory of mind abilities. Estes (1998) gave children a task which adults solve using mental rotation. Children who performed well at the task described their behaviour in terms of mental activity; children who performed poorly did not. The results showed 4-year-olds to be much poorer than 6-year-olds, who were closer to adult-like performance. Estes suggests that increased awareness of one's own mental states may allow more use of mental imagery. Theory of mind abilities might therefore play more than one role in the ability to reverse.

The hypothesised relationship between the ability to reverse and developing inhibition and mental imagery should be studied directly in future research. The visual search hypothesis is also empirically testable through observing eye-movements. Children's fixation behaviour should change after they start to pass the Production task. Furthermore, reversals should correspond to fixation of specific parts of the image. Past research has addressed this latter issue, but has been unable to determine whether fixation changes caused reversal, or reversal caused subjects to alter their fixation points (e.g. Ellis & Stark, 1978). Advances in eye-tracking equipment might now allow the issue of cause and effect to be teased apart. The issue of differing eye movement patterns after discovery of the ambiguity of the image has not yet been addressed, either with adults or children.

CONCLUSION

The present study advances our understanding of the phenomenon of reversal of ambiguous figures. We found that the ability to acknowledge both interpretations of an ambiguous figure arises about the age of four years. This is related to development of false belief understanding. We also found, like Gopnik & Rosati (2001), that there was a lag of roughly one year between understanding false belief and experiencing reversal. However, we found no specific relationship between reversal and complex understanding of ambiguity, indexed by the ability to pass the Droodle task. This should not be surprising: previous theoretical analyses of the process of reversal suggest that understanding of the ambiguous nature of the stimuli may be necessary but is not sufficient to achieve reversal. Some additional process is required – either through the use of mental imagery or in directing attention to other parts of the figure. We argue that the lag is explained by the difficulty of this additional process. The imagination hypothesis is most plausible, since it clearly requires high executive functioning and good mental imagery, both of which develop rapidly at around the age of four years. Both the imagination and visual search hypotheses allow clear empirical predictions, which can now be tested.

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<u>Footnote</u> (p. 11)

[1] All correlations in this paper are Pearson's r. The point biserial and phi correlations, which are special cases of Pearson's r, are used when one or both variables are dichotomous, respectively (Hinkle, Wiersma, & Jurs, 1979).

Table 1.

The percentage of children passing the tasks of Experiment 1.

	Age groups				
	3;3	3;10	4;7	5;2	Overall
n =	18	19	19	17	73
False belief	28	48	84	88	62
Droodle	11	21	29	77	34
Production	28	47	74	94	47

Note. For the Production task, the pass criterion is at least 2 out of 3 trials correct.

Table 2.

The percentage of children producing 0 to 3 pairs in the Production task of Experiment 1.

	Age groups				
	3;3	3;10	4;7	5;2	Overall
n =	18	19	19	17	73
Pairs produced					
0	44	16	5	0	16
1	28	37	21	6	23
2	11	32	0	12	14
3	17	16	74	82	47

Table 3a.

Intercorrelations between age and the experimental tasks of Experiment 1.

	False Belief	Droodle	Production
Age	.50***	.46***	.62***
False Belief	---	.33**	.47***
Droodle		----	.41***

Table 3b.

Age-partialled correlations between the experimental tasks of Experiment 1.

	Droodle	Production
False Belief	.13	.24*
Droodle	----	.18

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 4.

The percentage of children passing the four tasks of Experiment 2.

	Age groups			
	3;10	4;8	5;4	Overall
n =	21	23	21	65
False belief	48	74	95	72
Production	43	78	86	69
Droodle	5	39	57	34
Reversal	19	26	57	34

Table 5a.

Intercorrelations between age and the experimental tasks of Experiment 2.

	False Belief	Droodle	Production	Reversal
Age	.49***	.47***	.52***	.35**
False Belief	---	.30*	.43***	.30*
Droodle		----	.44***	.31*
Production			---	.09

Table 5b.

Age-partialled correlations between the experimental tasks of Experiment 2.

	Droodle	Production	Reversal
False Belief	.09	.24	.16
Droodle	----	.26*	.18
Production		---	-0.12

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Figure legends:

Figure 1a. The duck-rabbit stimulus, alone and with disambiguating context pictures.

Figure 1b. The vase-faces stimulus, alone and with disambiguating context pictures.

Figure 1c. The man-mouse stimulus, alone and with disambiguating context pictures.

Figure 1d. The Eskimo-indian stimulus, alone and with disambiguating context pictures.