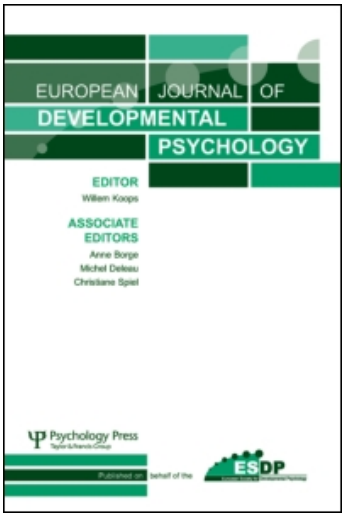

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Children's understanding that ambiguous figures have multiple interpretations

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Children's understanding that ambiguous figures have multiple interpretations

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In three experiments we compared 5- and 6-year-old children's understanding of multiple interpretations arising from an ambiguous figure (e.g., the duck/rabbit) and other ambiguous partial input. Children found it equally easy to switch between alternative interpretations of ambiguous figures and partial views (Experiment 1, $N = 19$) and more difficult to accept two characters' conflicting interpretations of ambiguous figures, than partial views (Experiment 2, $N = 29$). Children found it more difficult to accept explicitly that one stimulus could simultaneously give rise to two interpretations, than to switch between them (Experiment 3, $N = 40$). Children's handling of multiple interpretations was not primarily affected by the type of input, but results suggest that there are two distinct stages in children's handling of multiple interpretations.

Keywords: Ambiguity; Uncertainty; Knowledge; Theory of Mind; Communication.

When do children really understand that a single piece of information can have more than one interpretation? It is well known that children as young as 18 months behave as if objects can prompt different reactions in different people, for example that one person might adore broccoli and another dislike it (Repacholi & Gopnik, 1997). Five-year-olds' nonverbal behaviour (eye movements and response latencies) discriminates between ambiguous and unambiguous input (e.g., Nilsen, Graham, Smith, & Chambers, 2008; Plumert, 1996; Sekerina, Stromswold, & Hestvik, 2004) and they report the two interpretations of ambiguous figures such as the duck/rabbit (Figure 1; Gopnik & Rosati, 2001; Rock, Gopnik, & Hall, 1994). At around 7 years children begin to acknowledge explicitly that partial messages, which have

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multiple possible meanings, can be interpreted in different ways (Carpendale & Chandler, 1996).

There are various types of input that give rise to multiple interpretations and these interpretations vary in their validity. Our main aim in this paper is to explore what kinds of interpretations children think can be made of ambiguous figures, such as the duck/rabbit picture (Figure 1). In this case the ambiguity is inherent in the stimulus: there is a single object that can be seen as a rabbit or a duck. Either interpretation is equally valid. With other stimuli ambiguity comes about because of the wider context. For example, when there are several objects, a tomato, a strawberry and a banana, and someone chooses a "red one", we do not know to which they mean to refer. The message is partial and does not convey enough information to decide between the two possible interpretations. Similarly, if one could only see a small part of a picture of one of the fruits, an uninformative red patch, the uncertainty about which it is arises not because of the view itself but because two objects are red. Partial messages and views differ from ambiguous figures in that there is one fact of the matter: one intended referent of the message or one hidden object. Partial messages and views differ from each other in that the former have a symbolic relationship with their referent but the latter do not. However, in terms of the interpretations that are possible and the validity of these interpretations, they are similar and for our purposes they will be grouped (see Robinson & Robinson, 1982, who demonstrated that children treat partial messages and views in the same way). Note that in the referential communication literature these stimuli are often referred to as ambiguous, but here we will call them partial in order to

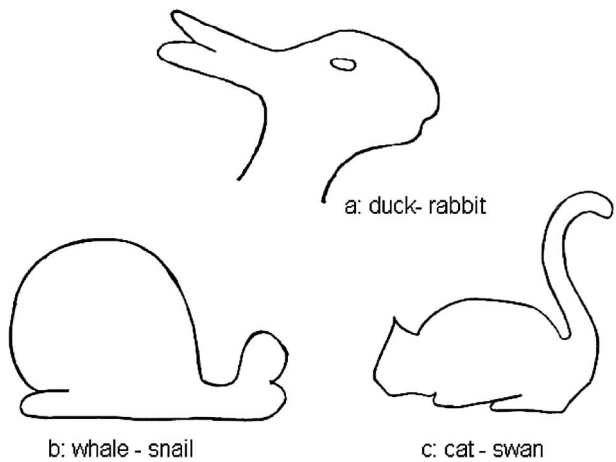

Figure 1. Ambiguous figures stimuli.

distinguish them from ambiguous figures. There are other types of stimuli that can have multiple interpretations, such as homonyms (e.g., ''bank'' can mean river bank or financial bank). Heard out of context these behave like ambiguous figures: they are inherently ambiguous and both interpretations are equally valid. However, spoken in communication, ''I am going to the bank'' they are like partial messages, in that the description ''bank'' does not fully disambiguate its possible referents and allow one to decide between the multiple possible interpretations.

Our interest is to identify different ways in which children can handle multiple interpretations, in particular those that arise from ambiguous figures like the duck/rabbit. Developmental studies of these interesting stimuli have to date looked only at children's ability to consider their multiple interpretations sequentially. Gopnik and Rosati (2001) found that once children had been informed of the two possible interpretations, they experienced reversals from 5 years of age. Reversals are the perceptual phenomenon where the picture flips between appearing as a duck and a rabbit. Doherty and Wimmer (2005) asked children to give different verbal interpretations of ambiguous figure stimuli in their production task. For example, the experimenter says, ''duck'' and the child responds, ''rabbit''. The production task is a simple way to show that the child can identify the different possible interpretations, although it does not require that children have any metacognitive understanding that one stimulus can be interpreted in two different ways.

Other tests of children's handling of multiple interpretations involve acknowledging that it is possible simultaneously to make more than one interpretation of a stimulus. These tests have been used with partial messages and views, and 5-year-olds perform very poorly. When they encounter partial messages, for example, when a speaker refers to ''the red one'' and there are two red objects, children under 7 or 8 years tend to say that the message was a good one (Bearison & Levey, 1977; Singer & Flavell, 1981), fail to seek disambiguating information using questions (Ironsmith & Whitehurst, 1978) or behavioural strategies (Beck & Robinson, 2001; Beck, Robinson, & Freeth, 2008), and are confident in the interpretations they make of ambiguous input (Robinson & Robinson, 1982; see also Bearison & Levey, 1977; Flavell, Speer, Green, & August, 1981). It has been claimed that children need to develop their representational ability (e.g., Apperly & Robinson, 1998), their executive control (e.g., Speer, 1984), or their problem-solving skills (e.g., Acredolo & Horobin, 1987) before they can master such problematic partial input.

Thus, there are two groups of tasks that have been used to investigate multiple interpretations: those that require switching between interpretations and those that test the explicit understanding that multiple interpretations can arise simultaneously. These have been used to explore

children's understanding of the multiple interpretations that arise from ambiguous figures and partial input respectively. We wanted to complete the picture by testing whether children are able to acknowledge explicitly that ambiguous figures can have multiple interpretations (rather than just switch between them) and whether children can switch between multiple interpretations of partial input. These data are needed because there are two possible reasons for the difference in difficulty in the literature. One is that it is easier to switch between multiple possibilities than it is to acknowledge the ambiguity explicitly, i.e., that there are two distinct stages in children's handling of multiple interpretations. The other is that there is some difference in the stimuli that makes it easier to think about multiple possibilities arising from ambiguous figures than partial input.

One reason that ambiguous figures might be particularly easy to handle is that they do not have a single objectively correct interpretation and thus, it might be easier for children to acknowledge different possible interpretations when they know there is not a correct answer.[1] Partial messages and partial views do have an objectively correct interpretation or fact of the matter: there is one picture hidden behind a window, or the message does refer to one picture specifically. This may make it particularly difficult for children to acknowledge two possible interpretations.

Some recent evidence offers support to this interpretation. Robinson, Rowley, Beck, Carroll, and Apperly (2006) compared children's ability to prepare for multiple possible outcomes when the outcome had yet to occur and when it had happened but they were ignorant about the outcome. In the former case there is no fact of the matter and either possible outcome could occur. This is comparable to ambiguous figures that have no one interpretation. In the latter case there is a fact of the matter: one of the possibilities has occurred. This is more like partial messages or views. In the study, children had to catch a green or orange block that could emerge from a green or orange door. Five-year-olds were more likely to put a cup under each door when the block had yet to be chosen, than when it had been chosen and was already hidden behind one of the two doors. Thus, children were better able to handle multiple possibilities when there was no objectively correct answer (see also Robinson, Pendle, Rowley, Beck, & McColgan, 2009). In the realm of interpretations, children may find it easier to handle the multiple interpretations that can be made of ambiguous figures

[1]It is possible that an ambiguous figure could have one single intended interpretation, for example, if the artist had intended it to look like a duck, but it happened to look like a rabbit, but this is not how these stimuli are usually presented and it is not how we will present them in our studies. See general discussion for further discussion.

than of partial input, because in the latter, but not the former, there is a single correct interpretation.

There has been one previous study of whether children can explicitly acknowledge simultaneous multiple interpretations of ambiguous figures. In Carpendale and Chandler's (1996) study two dolls viewed an ambiguous figure and made different interpretations. The child was asked, "Is it OK for Mary to say it's a duck and Maxi to say it's a rabbit?" to which the correct answer should be yes (see discussion and data addressing this claim in Experiment 2). Five- and 6-year-olds tended to say "no" suggesting they were not prepared to accept that two people could simultaneously make different interpretations of an ambiguous figure. However, there are several reasons why one might want to replicate this finding. First, Carpendale and Chandler (1996) used classic ambiguous figures, rather than the child-friendly pictures that have been favoured in recent research (e.g., Ropar, Mitchell, & Ackroyd, 2003). Second, children had to give both an evaluation and an explanation of why one could give different interpretations of a particular stimulus. We were concerned that this might be especially taxing for children, especially given the relatively unfamiliar ambiguous figures stimuli. Third, although the authors checked that children were aware of both interpretations of the ambiguous figure, they did not detail how they did this. In recent studies an explicit disambiguation phase has been used, including disambiguated versions of the picture and these tasks have shown that children handle ambiguous figures well (Doherty & Wimmer, 2005; Gopnik & Rosati, 2001). Finally, since Carpendale and Chandler's study several papers have emphasized young children's competence with ambiguous figures, on reversal tasks for example (e.g., Gopnik & Rosati, 2001). This motivated us to test Carpendale and Chandler's claim that simultaneously holding in mind the multiple interpretations of ambiguous figures was really difficult.

Our aim, then, was to compare children's ability to switch between multiple interpretations and explicitly acknowledge simultaneous multiple interpretations that arise from different types of stimuli: ambiguous figures where there is no fact of the matter and partial input (messages and views) where there is an unknown fact of the matter. Doing this would inform us whether there are two distinct stages in children's understanding of multiple interpretations or whether the type of stimuli is more important and children find it unprecedentedly easy to acknowledge multiple interpretations arising from ambiguous figures. To make these comparisons we focused on 5- and 6-year-olds, as we were interested in differences in performance when presented with different stimuli. However, informed by our findings, future research should map out the developmental trajectory of handling multiple interpretations.

EXPERIMENT 1

Method

Participants. Nineteen children (9 girls) with a mean age of 5 years 7 months (range 5;3–6;2) participated. Children attended a primary school in Solihull, UK, and came from a variety of socioeconomic backgrounds.

Materials. We used three ambiguous figure drawings (duck/rabbit, whale/snail, cat/swan) drawn in (3 mm) black pen on A4 white paper (Figure 1). For each picture there were two disambiguated versions, with added details in colour. The disambiguated versions of the duck/rabbit were slightly rotated to facilitate interpretation. We used three sets of four pictures ($\sim$ 10 cm square) for the partial message task. In each set two pictures shared a common attribute on which an ambiguous clue was based, for example, in one set there was a black and white rabbit, a black and white cow, a ginger cat, and a brown horse. The partial message was "It's black and white". A duplicate set of pictures was printed on individual cards. We also used a small toy bear.

Procedure. Children were tested individually in a quiet area of the school. Each child participated in both the ambiguous figures production task and the partial message production task. The order of the two tasks and the order of trials within each task were counterbalanced between children.

Ambiguous figures production task. The procedure was modelled closely on Doherty and Wimmer (2005). The experimenter told the child, "I have some funny pictures for you, shall we have a look? Now all these pictures can be two different things, OK?" The first ambiguous figure was presented, e.g., duck/rabbit and the child was asked, "What do you think this is?" If children gave an inappropriate interpretation the experimenter said, "OK, show me how it can be that", any child who responded in this way then realized that this interpretation was not possible. If any children did not give an interpretation the experimenter prompted them, "I know, it could be a rabbit, couldn't it." If children gave one of the two appropriate interpretations (duck or rabbit) the experimenter concurred and showed him/her the disambiguated version saying, "That's right, like this." The child was then told, "But look, it can be something else too." The experimenter showed them the other disambiguated version. After each interpretation, the experimenter asked children to point out distinguishing features (e.g., the rabbit's ears, the duck's beak) to confirm they had made this interpretation. Each ambiguous figure was disambiguated in this way.

There then followed the test phase. The experimenter said, ''We're going to play a game now. Remember all these pictures can be two different things. Now I'm going to say one thing and I want you to say the other thing, OK?'' The first ambiguous figure was placed on the table, and the experimenter said (for example), ''This is a rabbit. What else can it be?'' If the child responded ''duck'' s/he was scored as correct. If the child said, ''rabbit'' the experimenter said, ''But I've already said that it's a rabbit. What else can it be?'' If the child still did not give the correct answer after a pause of 10 seconds, the experimenter said, ''I know! It can be a duck can't it?'' Each picture was presented twice, and the experimenter gave the alternative interpretation on the second presentation (in this example ''duck'').

Partial messages production task. Children were introduced to the toy bear, Winnie. Each sheet of four pictures was placed on the table, one at a time, and the child named each picture and its colour. The experimenter said, ''We're going to play a game with these pictures now. I'm going to choose one, OK, and I'm going to give you and my friend Winnie here a clue about which one I've picked. Then Winnie is going to have to guess which one I've picked and I want you to make a different guess, OK?'' The experimenter put one picture sheet on the table and took the duplicate set of small cards. The experimenter picked one picture from the set, placed it face down on the table and said, ''Right then, I've got a set of the same pictures as you and I've picked one ... [for example] it's black and white. Winnie, which one do you think it is?'' The toy's answer was given by the experimenter, ''OK, he thinks it's the cow, what do you think it is?'' If children gave the alternative (the rabbit), they were scored as correct. If they repeated the toy's answer, the experimenter said, ''Yes, but Winnie has already said he thinks it's the cow, can you make a different guess?''

We included a metacognitive question about the child's knowledge, ''Do you really know it's a [rabbit] or don't you really know?'' The appropriate answer was to admit ignorance. This required simultaneously acknowledging both possible interpretations of the partial message. We did not ask this metacognitive question about the ambiguous figures because it was not clear to us what the correct answer to a ''do you know'' question should be. Furthermore, because the child had seen which picture the experimenter had picked we did not repeat the partial messages production task for each trial (as with the figures). Thus, children had only to give one alternative in this task.

Results and discussion

On four production trials children changed their answers following the prompt (two on figures trials, and two on message trials), and on only one

trial did the child then give an appropriate answer. Thus, we counted children as giving an appropriate answer only if they had done so before the prompt. We summed performance across the three trials see Table 1.

First, we examined whether our ambiguous figures production task results were similar to those found by Doherty and Wimmer (2005). Children were coded as correct if they gave the appropriate alternative answer on presentations of each picture, i.e., "rabbit" when the experimenter said duck, *and* "duck" when the experimenter said rabbit ("Doherty & Wimmer, 2005, scoring" in Table 1). To pass the task children had to do this for at least two of the three ambiguous figures. In the original paper, 5-year-olds performed very well: 94% (Experiment 1) and 86% (Experiment 2) passed. Using the same criterion 84% of our sample passed this task. We confirmed that 5-year-olds find it easy to give alternative interpretations of ambiguous figures.

We wanted to compare performance on the ambiguous figures and partial messages production tasks. There was only one presentation of each stimulus on the partial messages task (children had only to say "rabbit" to the toy's "cow"), but two presentations on the ambiguous figures task (following Doherty & Wimmer children had to say "duck" to the experimenter's "rabbit" and later "rabbit" to the experimenter's "duck"). To make a fair comparison we recoded children's performance on the ambiguous figures production task scoring them as correct if they gave the correct answer on the first part and ignoring the second part, i.e., if they said "duck" to the experimenter's "rabbit", but ignoring whether they went on to say "rabbit" to the experimenter's "duck". These results are "First presentation scoring" in Table 1. A Wilcoxon signed ranks test showed no difference in performance on the partial messages and ambiguous figures production tasks $Z = -1.5$, $p = .13$.

Performance on the metacognitive question was in line with the literature (e.g., Beck & Robinson, 2001). Children found it difficult to say that they did not know the referent of a partial message. Only seven children performed

TABLE 1
Performance on trials in Experiment 1

	Total number of correct trials			
Trial types	*0*	*1*	*2*	*3*
Ambiguous figures production				
Doherty & Wimmer (2005) scoring	0	3	5	11
First production scoring	0	1	5	13
Partial message production	0	0	2	17
Partial message metacognitive	8	3	1	7

perfectly on all trials, and children said (incorrectly) that they did know on 53% of trials. As is clear from Table 1 children found it easier to give an alternative interpretation on the partial message production task than they did to acknowledge ignorance on the metacognitive task. Comparing the number of children who performed perfectly on each task showed this effect very clearly. Ten children passed the production task but not the metacognitive task, none showed the reverse pattern. This was significant using a McNemar test $N = 19$, $\kappa = 0$, $p = .002$.

Thus, we replicated Doherty and Wimmer's finding that 5-year-olds can give alternative interpretations of ambiguous figures. Children could also give alternative interpretations of partial messages. It was equally easy for them to switch between multiple interpretations of ambiguous figures as it was to switch between the interpretations of partial messages. However, these children found it difficult to consider both interpretations of the partial message simultaneously. Strikingly, children claimed to know the correct referent immediately after they and a puppet had given conflicting interpretations. This is our first evidence to support the possibility that there are two distinct stages in children's handling of multiple possibilities.

In Experiment 1 we found no evidence that the difference in stimuli was affecting children's performance when they had to switch between interpretations. In Experiment 2 we tested whether children's ability explicitly to acknowledge two interpretations simultaneously was affected by the stimuli.

EXPERIMENT 2

We used an improved version of the Maxi/Mary task devised by Carpendale and Chandler with child-friendly ambiguous figures and an explicit disambiguation phase. We made a direct comparison between ambiguous figures trials and those where ambiguity arose from a partial view. In the partial view condition, children saw two red pictures, a tomato and a strawberry. One was hidden behind a window so that only a small patch of red could be seen. Maxi and Mary made their contrasting interpretations based on this partial view. In these trials although there were two possible interpretations there was one correct answer. In the ambiguous figures conditions Maxi and Mary made contrasting interpretations based on a duck/rabbit figure (for example). In these trials there was no one correct answer as to how the picture should be interpreted. We used a test question employed previously by Carpendale and Chandler: after each character had made his or her interpretation the child was asked to evaluate them, "Is that OK?". We thought the appropriate answer was to say "yes" when there were two conflicting interpretations and either was possible given the input:

i.e., it is OK for two people looking at a patch of red through a window to make different interpretations "a tomato" and "a strawberry". It is also OK for two people looking at an ambiguous duck/rabbit to give two different interpretations "a duck" and "a rabbit". To confirm our expectations, we ran a version of the task with adult participants.

Method

Participants. Twenty-nine children (15 girls) ranging in age from 5;3 to 6;2 participated (we did not have the individual ages to calculate the mean age for this sample). Children attended a primary school in Birmingham, UK, that served a predominantly working-class population. Thirty-three adults (29 women) with a mean age of 19 years and 11 months (range 18;3–42;10) were recruited from an undergraduate psychology programme and participated for course credit.

Materials. Adults completed a pen and paper version of the task, whereas children saw cards with pictures on. In the child version of the ambiguous figures task we used the duck/rabbit and whale/snail figures drawn in black ink on A4 paper. We also used pictures of a flower and a dog for control trials. For each target picture there were two smaller coloured pictures, used for disambiguation in the experimental trials (approximately 15 cm × 10.5 cm). For the control trials one smaller picture was a coloured version of the target and one was a different picture, for example a flower and a tree for the flower target. For the child version of the partial view task there were four pairs of drawings (each approx. 15 cm square). The experimental sets were a red tomato, red strawberry, yellow banana, and yellow sun. The control pictures were a blue car, green train, purple pencil, and red book. A piece of white card with a 1 cm × 1 cm window cut in it, could be placed over each of these pictures so that only a patch of colour could be seen. We also used two dolls approx 15 cm tall.

The task given to adults was presented on eight A4 sheets of paper. Each sheet had one or two pictures at the top (e.g., a duck/rabbit or a car and a train) and below either two small pictures (e.g., a disambiguated duck and rabbit) or one picture (e.g., a small patch of green behind a window). Maxi and Mary's interpretations and the test question with two options "yes" and "no" were printed on each page.

Procedure. Each child was tested individually in a quiet area of the school. Children participated in both the ambiguous figures task and the partial view task. The order that tasks and trials within each task were presented were counterbalanced between children.

Children were introduced to the dolls, Maxi and Mary, and told they were going to play a game. On ambiguous figures trials there was first a disambiguation phase. For experimental trials a picture (e.g., duck/rabbit) was placed on the table, and the child was told that it was special. The experimenter then placed the two disambiguated versions on the table and asked the child to say what each was. The experimenter then explained that "this picture [the target] is special because it could be a duck or a rabbit" The disambiguated versions were removed and the dolls viewed the picture. The experimenter indicated each doll in turn as she said, "Maxi thinks it's a duck and Mary thinks it's a rabbit." She asked, "Is that OK?" The correct answer was "yes". For the control trials the procedure was the same, although the experimenter did not say that the target picture could have two interpretations during the equivalent of the disambiguation phase. Instead, she simply showed the child the larger and the two smaller pictures and they were named. The smaller pictures were removed and Maxi and Mary gave conflicting interpretations, e.g., "Maxi thinks it's a flower and Mary thinks it's a tree. Is that OK?" It is clearly incorrect for someone looking at a picture of a flower to say "it's a tree" so it was correct to answer "no" on these trials.

In the partial view task children saw and named two pictures for example, a tomato and a strawberry. The experimenter introduced a "magic window" and showed the child that when a card was placed behind it only a patch of colour could be seen—NB, we purposefully called it a magic window to make it comparable with the "special" picture in the ambiguous figures task. The experimenter mixed up the pictures, holding them face down and placed one behind the window. The two characters were positioned so that they could see the partial view. On experimental trials the patch of colour could be part of either picture (for example both were red), but on control trials the patch of colour could only be part of one picture. The experimenter indicated each doll in turn as she said, "Maxi thinks it's a strawberry and Mary thinks it's a tomato. Is that OK?" The correct answer was to say "yes" on the experimental trials (e.g., tomato/strawberry, both were the same colour) but "no" on the control trials (e.g., car/train, different colours).

Adults participated in small groups. Each participant was given a set of eight sheets with one trial on each (we did not counterbalance the order of the trials for the adults). Trials were the same as for the children: two each of ambiguous figures, ambiguous figures control trials, partial views, partial views control trials. For each trial there were pictures of the cards shown to children and the interpretations made by Maxi and Mary were described, "Maxi thinks it's a rabbit and Mary thinks it's a duck.". The test question was printed "Is that OK?" with two options "yes" and "no" and participants were asked to circle their answer.

Results and discussion

First, we confirmed that adults evaluated the interpretations in line with our expectations. McNemar tests confirmed that there were no differences between any items in pairs of trials (e.g., between the two ambiguous figures trials). Performance was in line with our expectations. Adults said it was OK for Maxi and Mary to give different interpretations on ambiguous figure trials (94% of trials) and partial view trials (85%), but it was not OK to give different interpretations on the ambiguous figure control trials (82%) or partial view control trials (85%). There were significant differences between the likelihood of saying "OK" on experimental and control trials for ambiguous figures, $Z = -5.203$, $p < .001$, and for partial views, $Z = -5.080$, $p < .001$. There was a borderline difference between ambiguous figure and partial view experimental trials, $Z = -1.89$, $p = .059$. The trend was for adults to be more likely to say it was OK to make two different interpretations of the ambiguous figure than the partial view (although only five people ever said it was not OK to give two interpretations of an partial view: two on both trials and three on one).

Children scored 1 where they gave an appropriate response, saying "yes" on experimental trials and "no" on control trials. We summed children's responses on the two experimental and control trials for each task, see Table 2.

No mistakes were made on control trials. When one character's interpretation was incorrect, children always said the different interpretations were not acceptable. Performance on the experimental trials was worse. A Wilcoxon signed ranks test showed that children were less likely to accept the two interpretations in the ambiguous figure trials than the partial view trials, $Z = -4.2$, $p < .001$. Interestingly, the adults' trend was in the opposite direction.

A large number of children scored 1 on each pair of experimental trials. We checked that children did not find one ambiguous figure or partial view trial easier to handle than the other. There was no evidence that this was the

TABLE 2
Responses to dual person multiple interpretations task in Experiment 2

	Number of correct responses		
Trial types	*0*	*1*	*2*
Ambiguous figure experimental	7	14	8
Ambiguous figure control	0	0	29
Partial view experimental	0	6	23
Partial view control	0	0	29

case: six children said it was not OK for Mary and Maxi to make different interpretations of the duck/rabbit, eight children said this for the whale/snail. Three children rejected the different interpretations of the tomato/strawberry and three the banana/sun.

Children found it difficult to accept explicitly that two people could make different interpretations of an ambiguous figure. Indeed, they found it more difficult than accepting two interpretations of an partial view. This goes against the possibility outlined in the introduction that children might find it particularly easy to accept multiple simultaneous interpretations of stimuli when there is no fact of the matter, in this case ambiguous figures. Instead, our findings are in line with the possibility that switching between interpretations and acknowledging multiple interpretations simultaneously are two distinct stages. Further support for this comes from the observation that children's performance in this study appears relatively poor compared to the production task used in Experiment 1. This fits the claim that switching between interpretations (the production task) is easier than acknowledging multiple interpretations simultaneously (the Maxi/Mary task). In the third experiment, we compared these two types of test directly.

In Experiment 3 we used a new task to test whether children could hold in mind multiple interpretations simultaneously. We speculated that the Maxi and Mary task may underestimate children's ability to do this because they may not fully understand how individual people make interpretations based on ambiguous stimuli. In the Maxi and Mary task two people made different, single, interpretations of the ambiguous figures. For example, Maxi said the picture was (only) a duck. Mary said it was (only) a rabbit. To pass this task children have to understand both that the figure gives rise to two possible interpretations and that in this situation people may commit to only one of them. Perhaps children understood that the ambiguous figure could give rise to two different interpretations but expected people to acknowledge both possible interpretations (it's a duck/rabbit). If this were the case it would indicate an interesting limit on children's understanding of how people make interpretations, but it leaves open the possibility that they are perfectly able to hold the multiple interpretations of ambiguous figures in their own mind. To avoid this problem in Experiment 3 we used a task in which two interpretations existed simultaneously in one mind. Would children be prepared to acknowledge that one mind could make multiple interpretations of ambiguous figures?

EXPERIMENT 3

We made the same comparison as in Experiment 2 between ambiguous figures and partial views. In this experiment the two possible interpretations were given by a single person. To convey this we used a thought bubble task,

similar to that used by Robinson et al. (2006). A character viewed the ambiguous stimulus and the child was shown three thought bubbles representing his possible thoughts. Two bubbles each contained one single interpretation and a third contained both possible interpretations. Based on the results of Experiments 1 and 2, we did not expect ambiguous figure trials to be any easier than partial view trials. However, we predicted that children would find the production task that required switching between interpretations easier than the thought bubbles task that required holding two possible interpretations in mind simultaneously.

Method

Participants. Forty children (22 girls) with a mean age of 6 years and 2 months (range 5;2–7;0) participated. Children attended a primary school in Birmingham, UK, and typically came from a middle-class background.

Materials. We used the same target and disambiguation pictures as in Experiment 2. We used a doll, Robin, and a card with three identical pictures of Robin with empty thought bubbles. Small copies of the disambiguated pictures were used to fill the thought bubbles.

Procedure. Children participated in an ambiguous figures thought bubble task, a partial views thought bubble task and an ambiguous figures production task. Half the children had the production task at the beginning and half after all other tasks. Ambiguous figures and partial view thought bubble tasks were presented in a counterbalanced order and the order of trials within these tasks (experimental or control) was also counterbalanced. We used the same introductory phases for the ambiguous figures and the partial views as in Experiment 2. Where the production task came first we disambiguated the ambiguous figures before this task.

In the ambiguous figures task, after the disambiguation phase, the experimenter moved the doll, Robin, to look at the picture. The experimenter laid out three alternative contents in the thought bubbles, describing them as they were placed: ''Robin thinks it's a duck'', ''Robin thinks it's a rabbit'', ''Robin thinks it could be both''. The three alternatives were shuffled on each trial and placed in a random order. The child was asked, ''What does Robin think it is?'' The correct answer was the ''both'' option. On control trials the correct response was the single picture that matched the target.

The partial views task followed the same procedure as Experiment 2 up to the point where a picture was hidden behind the window. Then the experimenter placed Robin so he could see the card and showed the child the three thought bubble options: ''Robin thinks it's a tomato'', ''Robin thinks

it's a strawberry''. ''Robin thinks it could be both.'' The correct response was ''both'' on experimental trials and the appropriate single interpretation on control trials.

The procedure for the production task was the same as that used in Experiment 1, although we used only the duck/rabbit and whale/snail figures. We did not prompt the child if they gave the same response as the experimenter. This was because only one child had revised their interpretation appropriately in Experiment 1.

Results and discussion

We first considered the control trials on the thought bubble tasks. No child ever said that Robin could be thinking of both alternatives when he was viewing a control picture. On a few control trials (11% partial views and 3% ambiguous figures) children said that Robin would be thinking about the other picture (e.g., the green train when he could see a patch of blue car through the window). Thus, performance overall was very good on the control trials.

Scores were summed so that children had a score out of 2 on each of three trial types, see Table 3. A Friedman test showed that the three trial types differed, $\chi^2(2) = 18.77$, $p < .001$. We used Wilcoxon signed ranks tests to make comparisons between them, making a Bonferroni correction ($p < .017$) for multiple tests. The production task ($M = 1.5$) was easier than either the ambiguous figures thought bubbles task ($M = 0.65$), $Z = -4.00$, $p < .001$, and the partial view thought bubbles task ($M = 0.93$), $Z = -2.94$, $p = .003$. The difference between the two thought bubbles tasks was not significant, $Z = -1.77$, $p = .078$. We note that the mean score on the figures task was lower than that on the view task. As in Experiment 2, we checked that one ambiguous figure trial or one partial view trial was not easier than the other. There was no difference between the two items in each task.

One concern with this comparison is that the tasks involve different chance baselines. In the production task children responding at chance have

TABLE 3
Performance on thought bubbles and production task in Experiment 3

	Total number of correct trials		
Trial types	*0*	*1*	*2*
Ambiguous figures production task	3	14	23
Ambiguous figures thought bubbles	19	16	5
Partial views thought bubbles	11	21	8

a one in two chance of answering correctly. In the two thought bubbles tasks children could pick one of three thought bubbles. We used chi-square tests to compare performance on each task with that expected by chance. Performance was better than chance on the ambiguous figures production task, $\chi^2(2, N = 40) = 23.60$, $p < .001$, and the partial views thought bubble task, $\chi^2(2, N = 40) = 7.22$, $p = .03$. Performance on the ambiguous figures thought bubbles task was no better than that expected by chance. The production task was clearly the easiest of the three tasks and performance was superior than that expected by chance. This comparison with chance also gives some indication that the partial view task might be easier than the ambiguous figures task.

Overall, our results were in line with the second possibility set out in the introduction: children found it relatively easy to switch between multiple interpretations of ambiguous input (ambiguous figures), but difficult to hold multiple interpretations in mind simultaneously. There are two distinct stages in children's ability to handle multiple interpretations. Furthermore, it is not easy for children to handle multiple interpretations of ambiguous figures.

GENERAL DISCUSSION

We set out to investigate the development of children's handling of multiple interpretations. We contrasted two explanations for current findings in the literature. First, that children might find it easier to switch between multiple interpretations than explicitly acknowledge simultaneous multiple interpretations. Second, that it might be the stimuli that were critical and that children might find it easier to handle multiple interpretations of ambiguous figures than other types of ambiguous input such as partial messages or views.

We found no support for the second possibility. Children found it no easier to handle multiple interpretations of ambiguous figures, than they did partial views or messages. Indeed, in Experiment 2 they found trials that involved ambiguous figures more difficult. In contrast, we found good evidence that performance is affected by what children have to do with the multiple interpretations. When they must deal with them sequentially, switching between interpretations, they find the task easy regardless of the input. When they have to acknowledge explicitly that one input can give rise to multiple interpretations, i.e., handle more than one interpretation simultaneously, 5- and 6-year-olds find this difficult.

We suspect that some people may have anticipated this finding. However, our studies were needed to make a direct test of the two possible explanations. No one had tested whether children find it easy to switch between interpretations of a partial message or view. We confirmed that

they did. On the other hand, although we knew that children could switch between interpretations of ambiguous figures, it was unknown whether they really understood that the one picture could give rise to multiple interpretations, i.e., whether they would acknowledge this explicitly. Findings in a related area of literature (Robinson et al., 2006) might predict that this is would be particularly easy for 5-year-olds. Although Carpendale and Chandler (1996) had suggested this was not the case, a more thorough test was needed. Children did not show a precocious understanding that ambiguous figures could give rise to multiple interpretations. Our studies also made the first direct comparison between "easy" and "difficult" tasks, confirming that the same children found it easy to switch between interpretations, but difficult to acknowledge them simultaneously (Experiment 1: production task and metacognitive task; Experiment 3: production task and thought bubbles task).

What do our studies tell us about children's handling of ambiguous figures? There is some indication that children found it more difficult to acknowledge multiple interpretations of ambiguous figures than ambiguous views. Rather than offer an easy way in to understanding multiple interpretations, might ambiguous figures be particularly difficult to view as ambiguous? One reason for this is that children are likely to have had little prior experience of ambiguous figures. They might be unsure as to whether there is a correct interpretation that they are supposed to give. We tried to avoid this by including a disambiguation phase in which children were shown that one could to view the figure in two ways, but it remains a possibility.

Might ambiguous figures be more difficult than other types of ambiguous stimuli for children to deal with because the child finds it difficult to inhibit the particular view they are currently perceiving? This explanation cannot account for good performance on the production task, when the inhibitory demands would have been similar. Furthermore, a similar need to inhibit a first interpretation is also present on the ambiguous view and message trials. Although the whole picture cannot be seen, children show a tendency to interpret these ambiguous stimuli (see Acredolo & Horobin, 1987; Fay & Klahr, 1996).

An alternative explanation is that these stimuli present a very particular type of multiple interpretation problem. Ambiguous figures appear exclusively as either one or the other view, i.e., the duck/rabbit is at any one point either a duck or a rabbit, but never both or a combination of the two. At the outset we wondered if it might be easy to acknowledge multiple interpretations of ambiguous figures, because they were both equally correct. However, it might be especially difficult for children to accept the legitimacy of the two interpretations that constantly switch back and forth. It would be interesting in future studies to confirm when children are able to

acknowledge simultaneous multiple interpretations of ambiguous figures. Related to this is an interesting possibility that young children may find the very construction of an ambiguous figure difficult to understand. Adults know that ambiguous figures are drawn so that they have multiple interpretations. However, perhaps children assume that the artist intended the picture to have one interpretation (e.g., a rabbit) but that the picture can also, mistakenly, be seen as a duck. This has not been given consideration in the developmental literature, but it is possible that children might perform differently on tasks where they are told that the figure had one intended meaning. For our current argument, this does not affect our claim that children found it easier to switch between multiple interpretations than acknowledge them simultaneously. However, future research may demonstrate that if children are told that the picture has one interpretation they may find it harder to switch between interpretations on a production task, or reject Maxi and Mary's different interpretations until they are somewhat older.

The issue of the artist's intentions makes an interesting new link to the theory of mind literature. Of course, one of the main forces behind research on partial messages was to investigate children's understanding of intention and communication. Recently, there has been much discussion of the relationship between understanding ambiguous figures and theory of mind, specifically false belief understanding. Gopnik and colleagues (Gopnik & Rosati, 2001; Mitroff, Sobel, & Gopnik, 2006) found correlations between the droodle task and ambiguous figures reversal. The droodle task involved children seeing a tiny part of a picture, which was uninterpretable, through a window. Once they had seen the uncovered picture they were asked what they had thought the picture was of before and what an uninformed friend would think the picture was of. Thus, the task involves handling a known to be correct interpretation and acknowledging an incorrect or outdated interpretation (NB, we believe this structure is more like a traditional false belief task, such as the deceptive box task, rather than "indexing an abstract understanding of ambiguity", p. 181, as Gopnik & Rosati, 2001, claimed). While Doherty and Wimmer (2005) failed to replicate this relationship, they did find correlations between their production task, the droodle and unexpected transfer false belief tasks. All these tasks involve some handling of multiple interpretations but can be passed by switching between these interpretations. In the case of the unexpected transfer (or deceptive box) and droodle tasks: there are not two equally veridical interpretations, one is the true state of affairs and one is mis- (or partially) informed. Similarly, one can pass the production task and report reversals by thinking at any one time about a single representation (treated as true) and perhaps an alternative false one. Perhaps young children can manage a true representation or interpretation and a known to be false representation,

but not two equally plausible interpretations simultaneously (see Beck, Robinson, Carroll, & Apperly, 2006, for a related argument about children's thinking about possibilities in time).

Finally, a related type of problem is understanding differences of taste. Different people can make multiple interpretations of certain stimuli such as films or food. In this case there is no correct interpretation. It would be an interesting question for future research to test whether these interpretations are easier for children to handle on all kinds of tasks. Carpendale and Chandler (1996) included examples of this type of interpretation in their study and found they were somewhat easier for children to handle than ambiguous messages or ambiguous figures. This was on a task where children had to hold multiple interpretations in mind simultaneously. We also know that children can switch between people's different preferences for food at a very young age (Repacholi & Gopnik, 1997). However, one important difference between these taste interpretations and the interpretations arising from ambiguous input that we considered here is that there are no constraints on the former. One can legitimately make any interpretation of a film: it may be unconventional but it cannot be wrong. The multiple interpretations we have considered in this paper are much more closely tied to the input. They are only interpretations in as much as they are appropriate readings of the stimuli.

Children's understanding of multiple interpretations develops between 4 and 7 years from being able to switch between different interpretations to being able to acknowledge multiple interpretations simultaneously. One potentially fruitful avenue for future research will be to relate these two aspects of handling multiple interpretations to children's developing executive function, especially attentional switching and working memory. We suggest that children's thinking about multiple possibilities has at least two distinct stages and is a complex and relatively slow developing ability, and development is likely to come about through exposure to different types of input and domain general developments in information processing.

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REFERENCES

Acredolo, C., & Horobin, K. (1987). Development of relational reasoning and avoidance of premature closure. *Developmental Psychology*, *23*, 13–21.

Apperly, I. A., & Robinson, E. J. (1998). Children's mental representation of referential relations. *Cognition*, *63*(3), 287–309.

Bearison, D. J., & Levey, L. M. (1977). Children's comprehension of referential communication: Decoding ambiguous messages. *Child Development*, *48*, 716–720.

Beck, S. R., & Robinson, E. J. (2001). Children's ability to make tentative interpretations of ambiguous messages. *Journal of Experimental Child Psychology*, *79*, 95–114.

Beck, S. R., Robinson, E. J., Carroll, D. J., & Apperly, I. A. (2006). Children's thinking about counterfactuals and future hypotheticals as possibilities. *Child Development*, *77*, 413–426.

Beck, S. R., Robinson, E. J., & Freeth, M. M. (2008). Can children resist making interpretations of ambiguous input? *Journal of Experimental Child Psychology*, *99*, 252–270.

Carpendale, J., & Chandler, M. (1996). On the distinction between false belief understanding and subscribing to as interpretive theory of the mind. *Child Development*, *67*, 1686–1706.

Doherty, M. J., & Wimmer, M. C. (2005). Children's understanding of ambiguous figures: Which cognitive developments are necessary to experience reversal? *Cognitive Development*, *20*, 407–421.

Fay, A. L., & Klahr, D. (1996). Knowing about guessing and guessing about knowing: Preschoolers' understanding of indeterminacy. *Child Development*, *67*, 689–716.

Flavell, J. H., Speer, J. R., Green, F. L., & August, D. L. (1981). The development of comprehension monitoring and knowledge about communication. *Monographs of the Society for Research in Child Development*, *46*, 1–65.

Gopnik, A., & Rosati, A. (2001). Duck or rabbit? Reversing ambiguous figures and understanding ambiguous representations. *Developmental Science*, *4*(2), 175–183.

Ironsmith, M., & Whitehurst, G. J. (1978). The development of listener abilities in communication: How children deal with ambiguous information. *Child Development*, *49*, 348–352.

Mitroff, S. R., Sobel, D. M., & Gopnik, A. (2006). Reversing how to think about ambiguous figure reversals: Spontaneous alternating by uninformed observers. *Perception*, *35*, 709–715.

Nilsen, E. S., Graham, S. A., Smith, S., & Chamber, C. G. (2008). Preschoolers' sensitivity to referential ambiguity: Evidence for a dissociation between implicit understanding and explicit behaviour. *Developmental Science*, *11*, 556–562.

Plumert, J. M. (1996). Young children's ability to detect ambiguity in descriptions of location. *Cognitive Development*, *11*, 375–396.

Repacholi, B. M., & Gopnik, A. (1997). Early reasoning about desires: Evidence from 14- and 18-month-olds. *Developmental Psychology 33*(1), 12–21.

Robinson, E. J., Pendle, J. E. C., Rowley, M. G., Beck, S. R., & McColgan, K. L. T. (2009). Guessing imagined and live chance events: Adults behave like children with live events. *British Journal of Psychology*, *100*, 645–659.

Robinson, E. J., & Robinson, W. P. (1982). Knowing when you don't know enough: Children's judgements about ambiguous information. *Cognition*, *12*, 267–280.

Robinson, E. J., Rowley, M., Beck, S. R., Carroll, D. J., & Apperly, I. A. (2006). Children's sensitivity to their own relative ignorance: Handling of possibilities under epistemic and physical uncertainty. *Child Development*, *77*, 1642–1655.

Rock, I., Gopnik, A., & Hall, S. (1994). Do young-children reverse ambiguous figures. *Perception*, *23*, 635–644.

Ropar, D., Mitchell, P., & Ackroyd, K. (2003). Do children with autism find it difficult to offer alternative interpretations to ambiguous figures? *British Journal of Developmental Psychology*, *21*, 387–395.

Sekerina, I., Stromswold, K., & Hestvik, A. (2004). How do adults and children process referentially ambiguous pronouns? *Journal of Child Language*, *31*, 123–152.

Singer, J. B., & Flavell, J. H. (1981). Development of knowledge about communication—Children's evaluations of explicitly ambiguous messages. *Child Development*, *52*, 1211–1215.

Speer, J. R. (1984). Two practical strategies young children use to interpret vague instructions. *Child Development*, *55*, 1811–1819.