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A developmental shift in processes underlying successful belief-desire reasoning

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Abstract

Young children's failures in reasoning about beliefs and desires, and especially about false beliefs, have been much studied. However, there are few accounts of successful belief-desire reasoning in older children or adults. An exception to this is a model in which belief attribution is treated as a process wherein an inhibitory system selects the most likely content for the belief to be attributed from amongst several competing contents [Leslie, A. M., & Polizzi, P. (1998). *Developmental Science, 1*, 247–254]. We tested this model with an 'avoidance false belief task' in which subjects predict the behavior of a character, who wants to avoid an object but who is mistaken about which of three locations it is in. The task has two equally correct answers—in seeking to avoid the location where she mistakenly believes the object to be, the character might equally go to the location where the object actually is, or to the remaining empty location. However, the model predicts that subjects will prefer one of these answers, selecting the object's actual location over the empty location. This bias was confirmed in a series of five experiments with children aged between 4 and 8 years of age. A sixth experiment ruled out two rival explanations for children's biased responding. Two further experiments found the opposite bias in adults. These findings support one selection model as an account of belief-desire reasoning in children, and suggest that a different model is needed for adults. The process of selecting contents for mental state attributions shows a developmental shift between 8 years of age and adulthood.

Keywords: Belief-desire reasoning; Inhibition; Selection Processing; Theory of mind

Social cognition rests on the ability to reason about other people's mental states. A major goal of research has been to discover how young children come to reason about beliefs, desires, and other mental states. Investigation of children's belief-desire reasoning has mainly concerned children's ability to reason about false beliefs. This ability is tested with the false belief (FB)

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task, which requires children to attribute a false belief to another person or themselves. Children typically pass the FB task at four but fail at 3 years (for a recent meta-analysis see Wellman, Cross, & Watson, 2001).

The cause of young children's difficulty with the FB task has inspired intense debate (e.g., Scholl & Leslie, 2001). However, while much effort has gone to discovering *why* younger children fail the FB task, little attention has paid to *how* successful belief-desire reasoning occurs. We remain largely ignorant about the cognitive processes of children who succeed in belief-desire reasoning, and equally ignorant about these processes in adults.

We test the first detailed account of successful belief-desire reasoning (Leslie, 2000; Leslie & Polizzi, 1998). We replicate and extend previous findings that support the model as an account of children's belief-desire reasoning (Friedman & Leslie, 2004). We then provide evidence against the model as an account of belief-desire reasoning in adults. Our findings suggest a developmental shift between middle childhood (or later) and adulthood in the processes underlying belief-desire reasoning. We begin by reviewing findings that led to the development of the model, and then describe the model itself.

1. Approach and avoidance FB tasks

There is a striking contrast between children's performance on two versions of the FB task. In standard FB tasks (Baron-Cohen, Leslie, & Frith, 1985; Wimmer & Perner, 1983), children view a scenario in which a girl, Sally, wants to obtain a frog, sees it go under a red box, but is absent when the frog moves to under a blue box. Children are asked either where Sally thinks the frog is (Think question), or where she will look for the frog (Prediction question). Both questions have the same correct answer: Sally thinks the frog is in the red box and will look for the frog in this location. We will refer to the red box as the false belief location (FB-Location) because by indicating this location, the child correctly attributes a false belief to Sally. We refer to the blue box as the true belief location (TB-Location) because by indicating this location the child mistakenly attributes a true belief. Both questions are equally difficult, passed by most children at 4 years, failed by most at three.

In *avoidance* FB tasks, the protagonist wants to avoid the object about which a false belief is held. Suppose that Sally wants to put her clean hat away in a box, and wants to avoid putting it in the box with the frog. Children are again asked a Think question, and a slightly different Prediction question, "Which box will Sally go to with her clean hat?" In the avoidance FB task the Think and Prediction questions have different answers: Sally wants to avoid the FB-Location, where she falsely believes the frog to be, and so she will mistakenly go to the TB-Location, where the frog actually is. In contrast to approach FB tasks, the Think and Prediction questions in avoidance tasks differ greatly in difficulty. Four-year-olds who pass the Think question mostly fail the Prediction question (Cassidy, 1998; Leslie, German, & Polizzi, in press; Leslie & Polizzi, 1998).

Why do FB task passers fail to predict behavior in avoidance FB tasks? Failure does not result from difficulty understanding that people can have avoidance desires, because even 3-year-olds can reason about avoidance desire in the context of true belief (Cassidy, 1998; Leslie, Friedman, & German, in press). In addition, failure does not result because avoidance desire increases the *general* difficulty of the FB task: the need to consider avoidance desire does not increase the difficulty of prediction in a matched 'partial knowledge' control task (Friedman & Leslie, in press).

2. Selection Processing

To account for the difficulty of behavior prediction in the avoidance FB task, Leslie and Polizzi (1998) extended the Selection Processing account developed by Leslie and colleagues (Leslie & Thaiss, 1992; Roth & Leslie, 1998). The Selection Processing account claims that, in belief-desire reasoning tasks, children's main challenge is to select the correct target of the character's belief or action from amongst several plausible candidates. In the FB task, for example, children must try to select the correct target of Sally's belief about where the frog is from two plausible targets—the TB- and FB-Locations.

Selection has two stages. First, an unconscious "theory of mind mechanism" (ToMM) represents plausible candidate contents for the belief or desire to be attributed. Then an inhibitory process selects the most plausible candidate (Leslie & Thaiss, 1992; Roth & Leslie, 1998). Selection operates under the following rules:

1. The salience of candidate contents varies by degree and contents can have their salience decreased by inhibition.
2. Among the contents, typically one is true, the true-belief content. Initially, the true-belief content is most salient and will be selected by default.
3. For success in a FB task, the TB content must be inhibited so that its salience falls below that of the false-belief content.
4. Predicting the behavior of a character with an avoidance desire, the to-be-avoided target is identified and then inhibited so that an alternative target is selected.

Most 3-year-olds can predict behavior if an avoidance desire is in the context of a true-belief, suggesting that less inhibition is necessary to determine the target of an avoidance desire than to determine the target of a false-belief (see Leslie, Friedman, et al., in press; Leslie, German, et al., in press for further details).

The Selection Processing account explains key findings from research on children's belief-desire reasoning: 3-year-olds typically fail FB tasks because they lack the processing resources to inhibit the true-belief. True belief attribution is easy because it does not require the default to be inhibited. Some task manipulations, which ease 3-year-olds' difficulty with false belief, operate by reducing the salience of the true-belief (see Leslie, Friedman, et al., in press; Leslie, German, et al., in press; Surian & Leslie, 1999). In claiming that success in FB tasks requires inhibitory processing, the Selection Processing model is related to other accounts of belief-desire reasoning (e.g., Carlson, Moses, & Breton, 2002; Russell, Mauthner, Sharpe, & Tidswell, 1991).

3. Selection Processing in avoidance FB tasks

According to the Selection Processing account, behavior prediction in avoidance FB tasks is difficult because it requires 'double inhibition,' with one inhibition required for false belief and another for avoidance desire. If both inhibitions are simply combined and both applied to the true-belief content – because it is the default belief *and* the to-be-avoided target – then the false-belief and thus the FB-Location will be selected as target of the character's action. However, this is the wrong answer in this task. Leslie and Polizzi (1998) suggested two different ways that double inhibitions could combine to select the correct answer. One of these, the "Inhibition of Return" model, has recently been ruled out as an account of children's belief-desire reasoning (Friedman & Leslie, 2004; Leslie, Friedman, et al., in press; Leslie, German, et al., in press), while the other, the "Inhibition of Inhibition" model, has received support. Therefore, we will describe only the latter.

4. The Inhibition of Inhibition model

According to the Inhibition of Inhibition (IOI) model, for successful prediction in the avoidance FB task, inhibitions for belief and desire are applied in parallel so that they inhibit each other and cancel out. Because no inhibition reaches the true-belief target, it remains salient. Thus, the TB-Location is correctly selected as the target of the character's action. Fig. 1 depicts the operation of this model in the course of predicting behavior in the avoidance FB task.

We can test the IOI model of Selection Processing by adding a third location (Neutral-Location) to the avoidance FB task. With three locations, the task has two equally correct answers: In seeking to avoid the FB-Location Sally is equally likely to go to either the TB- or Neutral-Location. However, the IOI model predicts that children who pass will be biased to select the TB-Location over the Neutral-Location: Inhibitions for false belief and avoidance desire are applied to the true-belief in parallel, but cancel out without modifying its salience. The TB-Location, therefore, remains most salient, and is selected as the target of Sally's action.

Friedman and Leslie (2004) report an experiment confirming the above prediction. Here we seek to replicate this finding, using a wider range of materials and age groups, including adult subjects. We begin by testing whether children who pass the 3-Location avoidance FB task

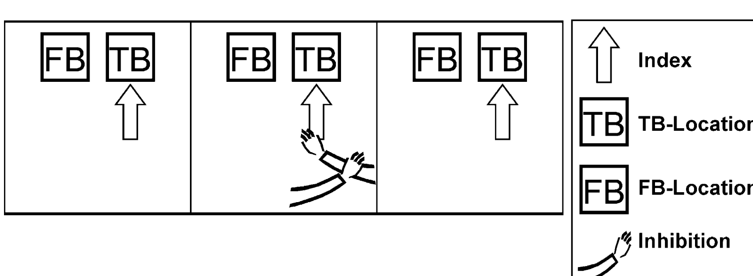

Fig. 1. The Inhibition of Inhibition model of Selection Processing. The representations of the TB- and FB-Locations are shown as boxes. Selection is illustrated by way the arrow or index, which points at the currently most salient candidate. To predict where a character with a false belief and an avoidance desire will go: (1) The true belief content is initially most salient. (2) Inhibitions for false belief and avoidance desire are applied in parallel, such that they cancel each other out. (3) The true belief content remains most salient, and so the TB-Location is selected as the target of the character's action.

have a bias to select the TB-Location over the Neutral-Location. We investigated this question in a series of five experiments that differ only in the details of the avoidance FB task used, and in the ages of the children tested. We present these five experiments together—both to ease comparisons between the experiments, and for brevity.

5. Experiments 1–5

Across five experiments, children were presented with three different versions of the avoidance FB task. In Experiments 1 through 3 we used three different versions of the avoidance FB task, with children who were mostly four and five. Experiment 4 tested slightly older children, and in Experiment 5 we tested 7- and 8-year-olds.

The IOI model predicts that children who pass the 3-Location avoidance FB task will predict that the character will go to the TB-Location. This prediction concerns children who *succeed* and so we only wanted to examine responses of reliable passers, not of children who pass by lucky guesses. To ensure that we were dealing with reliable passers, we only analyzed responses from children who passed all questions in the 3-Location avoidance FB task, and in a 2-Location FB task administered as a screen. The screening task was not used in Experiment 5 because children were seven and eight and assumed to be reliable passers.

5.1. Method

5.1.1. Subjects

In Experiment 1, 36 of 57 children passed all control (Memory, Reality, and Think) questions, but 28 of these children failed a Prediction question, leaving 8 reliable passers. In Experiment 2, 13 of 20 children passed all control questions, but 6 of these failed a Prediction question, leaving 7 reliable passers. In Experiment 3, 25 of 46 children passed all control questions, but 15 of these children failed a Prediction question, leaving 10 reliable passers. In Experiment 4, 13 of 17 children passed all control questions, but 4 of these children failed a Prediction question, leaving 9 reliable passers. In Experiment 5, control questions were passed by all 9 children tested, but one failed a Prediction question, leaving 8 reliable passers. Detailed information about children's ages in each experiment is provided in Table 1, which displays the average age and age range of all children tested, of control question passers, and of reliable passers.

5.1.2. Materials

All tasks made use of a foam board stage, differently colored boxes, and props used to enact the tasks. In Experiments 1–4, all materials differed between the two tasks administered, except for the stage.

5.1.3. Procedure

In Experiments 1 through 4, each child received a 3-Location avoidance FB task and a 2-Location version. Tasks were presented in counterbalanced order, except in Experiment 2 where the 3-Location task was always presented first. In Experiment 5, children only received the 3-Location task.

Table 1
Mean age and age range of all children tested, of children who passed all control questions, and of reliable passers, in Experiments 1–5

Experiment	Group	*N*	Mean age (*SD*)	Age range
1	All children	57	58.1 (7.3)	44–77
	Control passers	36	60.1 (7.3)	45–77
	Reliable passers	8	59.8 (8.8)	49–77
2	All children	20	59.0 (6.14)	49–70
	Control passers	13	59.8 (7.2)	49–70
	Reliable passers	7	60.6 (5.5)	51–69
3	All children	46	58.0 (8.1)	43–74
	Control passers	25	61.0 (8.3)	43–74
	Reliable passers	10	59.4 (7.7)	49–70
4	All children	17	65.5 (11.9)	52–99
	Control passers	13	68.9 (11.6)	55–99
	Reliable passers	9	69.1 (13.2)	55–99
5	All children	9	95.7 (7.7)	85–107
	Control passers	9	95.7 (7.7)	85–107
	Reliable passers	8	96.4 (7.9)	85–107

Several similar storylines were used to enact the tasks. Appendix 1 shows the storyline and protocols for the 3-Location version of the avoidance FB task used in Experiment 1. All tasks involved a character who wants to put an item in one of three boxes, but not with an animal. In 2-Location tasks, the character saw the animal under one box (FB-Location) but was absent when the animal moved to under another box (TB-Location). Three different versions of the 3-Location task were used—see Fig. 2 for a visual summary.

5.1.3.1. Experiment 1. The character first saw the animal under a box at the right or left end of the row of boxes (FB-Location), but was absent when the animal temporarily moved to under the middle box (Neutral-Location) and then moved to the final box (TB-Location).

5.1.3.2. Experiment 2. The character first saw the animal under the middle box (FB-Location) but was absent when it moved to under an end box (TB-Location). The Neutral-Location, the other end box, was never visited.

5.1.3.3. Experiments 3–5. The character first saw the animal under one end box (Neutral-Location), then saw the animal move to under the middle box (FB-Location), and was absent when the animal moved to the other end box (TB-Location).

Following presentation of each task scenario, children were asked Memory, Reality, and Think control questions, and a Prediction question.[1] Experiment 2 also included a Know control question asked prior to the Think Control question. To pass the Prediction question in 2-Location tasks children had to pick the TB-Location. To pass Prediction in 3-Location tasks, children could select either the TB-Location or the Neutral-Location or both.

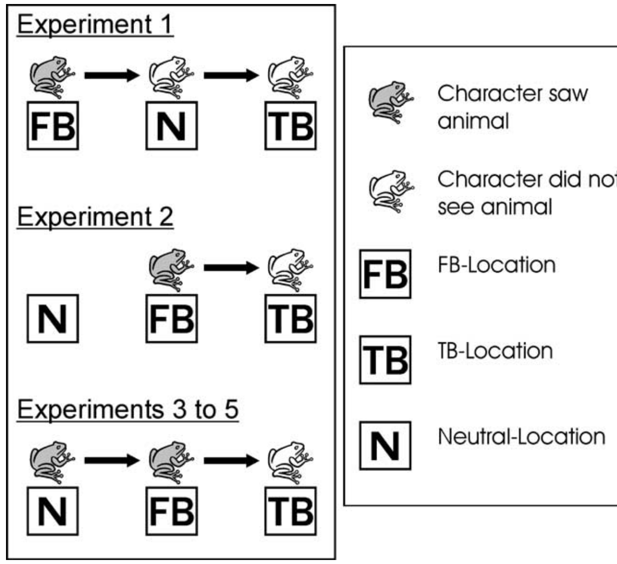

Fig. 2. Versions of the 3-Location avoidance FB task used in Experiments 1–5.

Direction of the animal's motion was counterbalanced: For half of the children in each experiment, the animal moved from the right to the left in the 3-Location task and from the left to the right in the 2-Location task. Direction of movement was reversed for the remaining children.

5.2. Results

In each experiment, reliable passers were biased to select the TB-Location over the Neutral-Location in response to the Prediction question in the 3-Location avoidance FB task. In Experiment 1, 7 (87.5%) of 8 reliable passers selected the TB-Location, and one selected both correct answers and was conservatively scored as selecting the Neutral-Location (Binomial sign test, $N = 8$, $x = 1$, $p = .035$, one-tailed). In Experiment 2, all seven (100%) reliable passers selected the TB-Location (Binomial, $N = 7$, $x = 0$, $p = .008$). In Experiment 3, 8 (80.0%) of 10 reliable passers selected the TB-Location, one selected the Neutral-Location, and one selected both correct answers and was conservatively scored as selecting the Neutral-Location (Binomial, $N = 10$, $x = 2$, $p = .055$, one-tailed). In Experiment 4, 8 (89%) of 9 reliable passers selected the TB-Location, and one indicated the Neutral-Location (Binomial, $N = 9$, $x = 1$, $p = .02$, one-tailed). In Experiment 5, 7 (87.5%) of 8 reliable passers selected the TB-Location, and the remaining child selected the Neutral-Location (Binomial sign test, $N = 8$, $x = 1$, $p = .035$, one-tailed).

Summing across the five experiments, there were 42 reliable passers and 37 (88.1%) selected the TB-Location ($p < .0001$, one-tailed). Table 2 summarizes these results. When we included non-reliable passers, the same bias remained: counting children who passed all Control questions and the Prediction question in the 3-Location task (but who may have failed

Table 2
Reliable passers selecting the TB- and Neutral-Locations in Experiments 1–5

Experiment	TB-Location	Neutral-Location or both answers
1	7	1
2	7	0
3	8	2
4	8	1
5	7	1
Combined	37	5

Prediction in the 2-Location task), 84% chose the TB-Location (Binomial, $N = 49$, $x = 8$, $p <$ .0001, one-tailed).

5.3. Discussion

Children who passed the 3-Location avoidance FB task were biased in answering the Prediction question. In all five experiments, children more often selected the TB-Location over the Neutral-Location, though both answers are equally correct. The IOI model predicted this bias and we were able to replicate and extend the findings of Friedman and Leslie (2004).

Biased responding was found using three different versions of the 3-Location avoidance FB task, suggesting that the bias is robust. Had we only administered one version of the task, then it might have appeared that the bias was an artifact specific to that version of the task. For example, in Experiment 1 the Neutral-Location was always the middle box in the row of boxes, and the TB-Location always an end box. Biased responding in this version of the task might result from some spatial bias that made the middle box less salient than those at the ends of the row. However, in the remaining experiments both correct locations were end boxes, ruling this explanation out.

We next tested two rival explanations for children's bias to select the TB-Location. Children might have followed an *Object Bias* and selected the TB-Location because it contained an animal whereas the Neutral-Location was empty. Alternatively, children may have a *Failure Bias* and may have selected the TB-Location, because that location would frustrate the character's desire to avoid the animal. Although Friedman and Leslie (2004) have supported the IOI model of Selection Processing over these rival explanations, we sought further evidence.

To test the rival explanations, we devised an avoidance Ignorance task: Sally wants to put her clean hat away under one of two boxes so that she can keep her hat clean. After confirming that both boxes are empty, she goes to get her hat. During her absence, a dirty frog enters and children are asked whether Sally would want to put her clean hat with the dirty frog. The frog then goes under one box (Object-Location) with the other left empty (Neutral-Location). Children are then asked whether Sally knows that there is a frog in the Object-Location (Know question), followed by a Prediction question. In this task, Sally has no belief about the location of the frog because she has never seen it.

Like the 3-Location avoidance FB task, the avoidance Ignorance task has two equally correct answers about where the character will go—a location holding an object that the character would want to avoid, and an empty location. Both rival explanations predict that children will select the Object-Location, because it contains an object (Object Bias), or because it frustrates Sally's desire to avoid a dirty location (Failure Bias).

The IOI model, in contrast, predicts no bias in the avoidance Ignorance task. Recall that the model is a model of successful performance. To succeed in this task, there should be no index for a belief about the frog because Sally does not have any belief about the frog. When asked to predict her action, an index for desire should be attracted to whichever target is the more salient. Because there is no principled reason for one target to be more salient than another, the index should go to either target about equally. There may be extraneous factors that boost one target over the other (a favorite color, for example), but if such factors play any role, they are outside the scope of the model. The main point is that, in contrast to the Object and Failure biases, the IOI model does not predict the same bias for the avoidance Ignorance task that it predicted for the avoidance FB task.

As in the previous experiments, we were interested in the responses of reliable passers, and so the avoidance Ignorance task was followed by a 2-Location avoidance FB task that served as a screen.

6. Experiment 6

6.1. Method

6.1.1. Subjects

Eleven children, between 5:5 and 6:3, mean = 5:11 years, *SD* = 2.84 months, completed the experiment. One child was rejected for failing the Prediction question in the 2-Location avoidance FB screening task. The remaining 10 children ranged between 5:5 and 6:3 (mean = 5:11, *SD* = 2.91 months).

6.1.2. Procedure

Children received the avoidance Ignorance task followed by a 2-Location avoidance FB task. This fixed order was used to ensure that performance on the Ignorance task was not biased by performance in the avoidance FB task. For half of the children the Object-Location was on the right and the Neutral-Location on the left, with sides reversed for the remaining children.

6.2. Results

Children in the avoidance Ignorance task showed no bias to select one location over the other. Of 10 children, 7 selected the Neutral-Location and 3 selected the Object-Location (Binomial, $N = 10$, $x = 3$, $p = .34$, two-tailed). Children's performance in this task differed significantly from that in the avoidance FB tasks of the previous experiments (Fisher's Exact, $p = .001$, two-tailed).

6.3. Discussion

The avoidance Ignorance task has two equally correct answers about where the character will go—a location containing an object to be avoided and an empty location. If children in the previous avoidance FB tasks had Object or Failure biases, then in the present task they should also have been biased to select the Object-Location over the Neutral-Location. Running counter to this, if anything, slightly more children selected the Neutral-Location. This finding rules out Object and Failure biases as accounts for children's bias in the avoidance FB task.

Were children actually biased toward the Neutral-Location? Even on a one-tailed test, we cannot support that statement on present results. However, suppose some children actually index the frog's location, as if Sally knew about the frog. This would be an error, of course, reflecting a "curse of knowledge." Such children might then inhibit that location because of the avoidance desire and predict that Sally will go to the Neutral-Location. We cannot tell from present results which children, if any, followed this scenario, so it is a topic for future research.

Having supported the IOI model over the rival explanations, we next investigated the 3-Location avoidance FB task in adults. Are adults also biased to select the TB-Location over the Neutral-Location?

Although adults may readily perceive both correct answers, sensitive tests may reveal biases produced by underlying reasoning processes, as shown in a number of cases (e.g., Gigerenzer, Todd, & ABC Group, 1999; Tversky & Kahneman, 1974), including social reasoning (Camerer, Loewenstein, & Weber, 1989) and even belief-desire reasoning (Mitchell, Robinson, Isaacs, & Nye, 1996). Pilot testing indicated that the dolls and props used in testing children were too 'babyish' for use with adults. Thus, we presented adults with the 3-Location avoidance FB task in cartoon form. Because we assumed that, unlike children, it would be obvious to adults that the task had two correct answers, we asked adults to pick the first answer that came to mind. We tested adults in two experiments. The experiments only differed slightly and so we present them together.

7. Experiments 7 and 8

7.1. Method

7.1.1. Subjects

Thirty adults were tested in Experiment 7, though five were rejected from analysis for failing the Prediction question and selecting the FB-Location. An additional 30 adults were tested in Experiment 8, and 4 were rejected for failing the Prediction question. In both experiments, all subjects were undergraduate students at Rutgers University and aged between 18 and 22 years.

7.1.2. Materials

Subjects received an instruction sheet and a cartoon depicting a 3-Location avoidance FB task. In Experiment 7 the cartoon depicts Mike who owns three identical sheds lined in a row. He sees his cat jump into one shed (FB-Location) but is absent when it jumps into another shed. A frame below the main cartoon instructs subjects to indicate which shed Mike will go to upon returning, given a desire to go to an empty shed. A sample cartoon appears in Appendix 2.

In Experiment 8, Mike has three cottages that he rents out. He sees a lizard crawl under the door of one cottage (FB-Location) and goes away to call the exterminator. During his absence, the lizard crawls into another cottage (TB-Location) and Mike meets a couple who want to rent out a cottage. Subjects were instructed to indicate which cottage Mike gives the couple keys for, given that he does not want to rent out the cottage containing the lizard.

Half of the cartoons in each experiment showed the animal moving from the middle location to the end location on the right, and the other half showed the animal moving to the end location on the left.

7.1.3. Procedure

Subjects were told that they would look over a cartoon and then answer a question about it on paper. Subjects were told that the question might have more than one correct answer, and that they should pick the first correct answer that came to mind.

7.2. Results

Subjects were biased to select the Neutral-Location over the TB-Location. In experiment 7, 25 subjects selected a correct answer, of whom 22 (88%) picked the Neutral-Location and 3 picked the TB-Location (Binomial, $N = 25$, $x = 3$, $p < .0002$, two-tailed). In Experiment 8, 26 subjects selected a correct answer, of whom 22 (84.6%) selected the Neutral-Location and 4 selected the TB-Location (Binomial, $N = 26$, $x = 4$, $p < .0003$, one-tailed).

7.3. Discussion

When giving the first answer that came to mind, adults were biased when predicting a character's behavior in the 3-Location avoidance FB task. However, the adult bias was toward the Neutral-Location—the opposite to that found in children.

After finding biased responding in Experiment 7, we worried that the bias might have resulted from an ambiguity in the Prediction question. Though we had intended subjects to indicate the first shed they thought Mike would go to, subjects may have wondered whether we were asking about where Mike would go eventually. They may have selected the Neutral-Location, then, because it is the only answer correct under both interpretations of the question. Experiment 8 was designed to avoid such ambiguity—it is clear that the question concerns the cottage key that Mike first gives the renters, and not whichever key he might later give them if they complain about the lizard in their cottage. However, the results were the same.

Adults were instructed to select the first correct answer that came to mind. This instruction was not given to children in Experiments 1 through 6. It is possible that children would have performed differently if they had received this instruction, or that adults would have performed differently if they had not. We are skeptical about this, although it is an empirical question and will need to be resolved in future experiments. The main reason we gave the instruction to adults was that in pilot studies adults took a long time before answering the Prediction question. We feared that perhaps adults were looking for hints as to whether one of the correct answers was somehow better, and that a prolonged effortful search would not reflect heuristic processing. Children did not show similar hesitation and therefore were not given the instruction. We assume that Selection Processing is a heuristic process (Leslie, Friedman, et al., in press; Leslie, German, et al., in press).

8. General discussion

The IOI model of Selection Processing provides the most detailed account to date of the role of inhibitory processing in the FB task and of how belief-desire reasoning operates. The model claims that successful attribution of false belief requires inhibitory processing to overcome a default tendency to attribute true belief (from the attributer's point of view). The model claims that inhibition is also necessary when predicting the behavior of a person with an avoidance desire, because predicting where the person will go requires first inhibiting what the person will avoid. Predicting behavior in the case of avoidance FB therefore requires 'double inhibition' and is more difficult than tasks involving single inhibition, like standard false belief or avoidance desire with true belief, or no inhibition, like true belief with approach desire. The model claims that, in 'double inhibition,' inhibitions for belief and desire cancel out without other effect, leaving the true-belief content uninhibited. The model therefore predicts that subjects succeeding in the 3-Location avoidance FB task will be biased to select the TB-Location as the target of the character's action, even though the Neutral-Location is equally correct. As far as we know, the IOI model is the only account of children's belief-desire reasoning to make *any* prediction about performance in the 3-Location avoidance FB task.

We tested the IOI model in children and adults. Children who passed the avoidance FB task were biased to select the TB-Location over the equally correct Neutral-Location (Experiments 1 through 5), replicating previous findings (Friedman & Leslie, 2004). Object and Failure biases were ruled out as possible explanations for children's bias to select the TB-Location—both of these rival accounts predicted that children should prefer the 'Object-Location' in the avoidance Ignorance control task, but this was not found (Experiment 6). Thus, the findings from Experiments 1 through 6 support the IOI model as an account of belief-desire reasoning in children.

Adults who passed the 3-Location avoidance FB task showed the opposite bias to children, and selected the Neutral-Location. This finding conflicts with the IOI model, and so a different account is needed to explain this. We might explain the adult bias with a different Selection Processing model, namely, the Inhibition of Return model (Leslie & Polizzi, 1998). This model has already been ruled out for children's belief-desire reasoning (Friedman & Leslie, 2004; Leslie, Friedman, et al., in press; Leslie, German, et al., in press) and is further contradicted by Experiments 1 through 5. In the Inhibition of Return (IOR) model, Selection Processing involves two distinct indexes, one to attribute belief and the other to predict behavior, and inhibitions for belief and desire are applied serially rather than in parallel. As Friedman and Leslie (2004) point out, the IOR model predicts a Neutral-Location bias in a 3-Location avoidance false belief task. It is possible, then, that IOR may capture adult heuristic belief-desire reasoning. We remain tentative on the question of whether IOR is a good model for adults pending further evidence. However, we might speculate that age-related increases in processing resources may allow a more sophisticated heuristics in which belief and desire are indexed and inhibited separately (see Leslie, Friedman, et al., in press; Leslie, German, et al., in press for further discussion of this model).

Other accounts might also explain the adult bias. For example, responding may have resulted from a bias towards granting the character's desire, or from 'the curse of knowledge' (Birch & Bloom, 2003; Camerer et al., 1989) or 'epistemic egocentrism' (Roysman, Cassidy, & Baron, 2003). Perhaps adults are far more prone to these errors than are children. These are excellent topics for future research.

Whatever the explanation, the difference between response biases in children and adults is startling. Developmental changes in belief-desire reasoning usually involve improvement with age (for an important exception, see Mitchell et al., 1996). However, our findings indicate a developmental change in the processes underlying *continuing successful* belief-desire reasoning.

An important goal for future research is uncovering the nature and cause of the developmental shift in processing we have identified. One goal will be to discover when children first readily perceive that the avoidance FB task has two correct answers. In Experiments 1 through 5, very few children selected both correct answers, and few selected the Neutral-Location itself. It is possible, then, that few children notice that the Neutral-Location is also correct. If so, then there may be two shifts between childhood and adulthood—the shift in biases reported here, and perhaps a shift from seeing one correct answer to seeing both.

A second goal will be to discover when the shift between biases occurs. Based on current findings, the shift should occur after 8 years but before 18. Neuroimaging studies have consistently identified the medial prefrontal cortex, especially the anterior paracingulate, as involved in processing FB tasks (Frith & Frith, 1999; Gallagher & Frith, 2003). The prefrontal cortex is thought to be crucial for inhibitory processing with different regions underlying successful inhibitory processing in children and adults (Durston et al., 2002). Furthermore, this region undergoes major development during puberty (Giedd et al., 1999). The developmental shift in belief-desire reasoning we have identified may be produced by the changes in inhibitory processing associated with puberty.

Notes

1. In Experiment 1, our second Memory control question in the 3-Location task ("Where did [animal] go after that?") was unclear—many children who otherwise passed pointed to the final location of the animal. For this reason we did not eliminate children who failed this question, but modified it in subsequent experiments: "Where did [animal] go *right* after that?"

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Appendix 1

Protocol for 3-Location FB task used in Experiment 1.

This is Billy and look what he has—it's a bone! Billy wants to put this bone away under a box. So he leaves the bone outside, and he goes into the room to look for a box to put it under. And look, there are three boxes here. What color is this box? What color is this box? And what color is this box?

Let's see if there is anything under the boxes. Anything under the black box? No, nothing. And under the yellow box? Nothing. And under the green box? A dog! But it's a sick dog, because it's got a toothache. Billy does not want to put the bone with the dog because then its tooth will hurt more.

Now Billy is going to go outside to get the bone, so he can put it under a box. Why does Billy not want to put the bone with the dog? Right, because he doesn't want its tooth to hurt more.

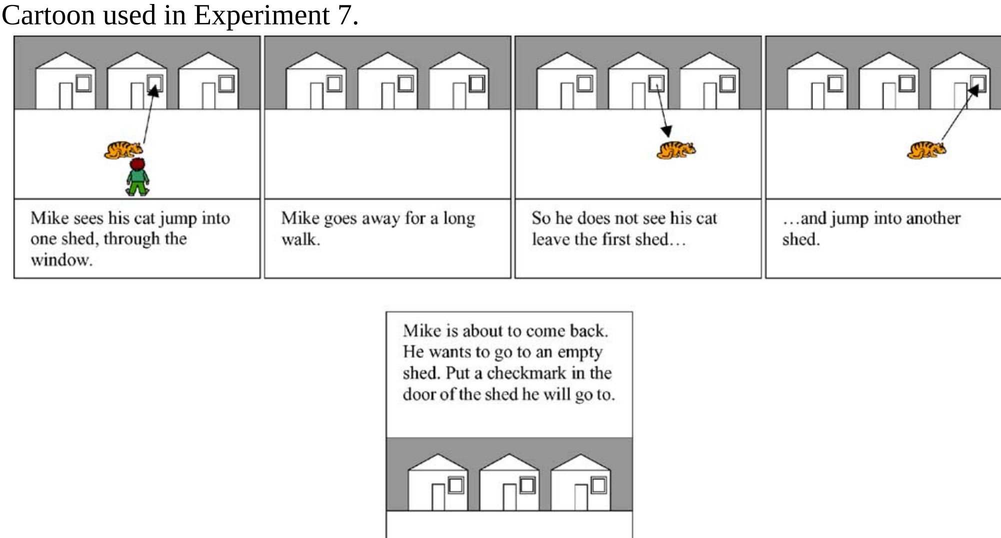
Now look what happens while Billy is gone: The dog crawls from under the green box, and it goes under the yellow box. And then, the dog crawls from under the yellow box and crawls under the black box. Did Billy see that? No!

Now Billy is going to come back with the bone to put it under a box, and I have some questions for you . . .

Memory 1: When Billy looked under the boxes in the beginning, where was the dog?
Memory 2: Where did the dog go after that?
Reality: Where is the dog now?
Think: Where does Billy think the dog is?
Prediction: Which box will Billy go to with the bone?

Appendix 2

Cartoon used in Experiment 7.



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