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Children's Sensitivity to Their Own Relative Ignorance:
Handling of Possibilities Under Conditions of Epistemic and Physical Uncertainty

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Abstract

Children were more likely correctly to specify possibilities when uncertainty resided in the physical world, and more likely to guess the outcome when objectively identical uncertainty arose from their own perspective of ignorance (epistemic uncertainty). In Experiment 1, 4-to 6-year-olds more frequently marked both doors from which a block might emerge when the outcome was undetermined, than when the block was hidden behind one door. In Experiment 2 (5-to 6- year-olds) and 3 (5-to 8- year-olds), children more frequently placed food in both possible locations when an imaginary pet was yet to be placed in a box, than when it was hidden in one. Results have implications for interpretive theory of mind and 'curse of knowledge'.

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Adults' and children's handling or mishandling of uncertainty have long been the focus of research attention. In the adult literature, a number of researchers have made a distinction between uncertainty which arises in the external world (for example about the fall of a die not yet thrown), and uncertainty which resides internally due to ignorance on the part of the observer (for example about the fall of a die which has been thrown but out of the observer's view). The latter is commonly labeled epistemic uncertainty; the former has been given various labels and here we shall use the term physical uncertainty. In the experiments reported here we compare children's handling of these two types of uncertainty and show that, as for adults, the variable is of psychological importance: Exactly the same probability is treated differently when uncertainty is epistemic rather than physical. In our tasks with children, however, the effect operates in the opposite direction from that found in the adult studies, and we speculate why.

In what follows we begin by summarizing the published research on children's handling of uncertainty, most of which involves procedures giving rise to epistemic rather than physical uncertainty. Then we show how adults respond differently to the two types of uncertainty in tasks unlike those used with children. Finally we set up our predictions for children's handling of the two types of uncertainty in tasks which derive from the existing developmental literature.

Children have a well documented tendency to under-estimate the uncertainty arising from limited information in a wide range of circumstances, to a much greater extent than adults. The literature on children's understanding of ambiguity highlights changes between around 5 and 8 years in children's acceptance of the possibility of alternative interpretations of limited input (e.g. Beal, 1988; Flavell, Speer, Green & August, 1981; Robinson & Robinson, 1982; Robinson, Goelman & Olson, 1983; Taylor, 1988), and this has been supplemented by more recent studies (Apperly & Robinson, 1998; Beck & Robinson, 2001; Carpendale & Chandler, 1996). Research on children's readiness to make undecidability judgements in reasoning problems gives results consistent with the work on ambiguity (e.g. Braine & Rumaine, 1983; Fay & Klahr, 1996; Klahr & Chen, 2003; Pieraut-le-Bonniec, 1980). By around 7 to 8 years many children demonstrate in various ways that they are aware that visual or oral input can be ambiguous, that a viewer or listener could make the wrong interpretation or would not know the correct interpretation, and that two viewers or listeners might legitimately make different interpretations. Younger children, in contrast, tend to make a single interpretation of information which affords more than one interpretation, tend to judge that they or another person knows the true interpretation when a judgement of 'don't know' would be appropriate, and tend to judge that limited oral or visual input tells or shows them enough to identify the correct referent.

On the other hand, 4- to 5- year olds are not completely insensitive to the distinction between informative and uninformative or partially informative information: They may hesitate prior to interpreting limited information (Plummert, 1996); they appropriately revise incorrect interpretations in the light of further clarifying information

(Beck & Robinson, 2001), and they recognize when they have gained sufficient information to identify a referent uniquely even though they respond inappropriately to insufficient information (Beck, Robinson & Freeth, 2005).

In all the tasks used in the studies cited above, uncertainty arises only because information is withheld from the participant, information to which he or she could in principle have access. For example in Klahr & Chen (2003) the experimenter made an object behind a screen so the child could not see which of a set of boxes was used, and children judged whether they "knew for sure" or could "only guess" which box had been used. Similarly, in referential communication tasks, the speaker has a particular intended meaning in mind and has typically chosen a real referent which is hidden from the child listener (e.g. Apperly & Robinson, 1998).

In a study of logical reasoning amongst 4- and 6- year-olds, Sophian and Somerville (1988) devised a game which was the inspiration for our procedures in the experiments to be reported. In Sophian and Somerville's (1988) game, a toy was hidden in one of several possible cups which were suspended in a rack above the table. The experimenter's hand moved across the cups in various sequences which either allowed the child to infer exactly where the toy was, or to narrow down the possibilities to two, three or four of the cups. Children's task was to place mats on the table where necessary to cushion the fall of the toy from the cup. Hence in this procedure, the toy was already in place, the experimenter knew which cup it was in, and it was only the child's limited perspective which gave rise to her uncertainty. The 4-year-olds as a group showed some sensitivity to uncertainty by placing more mats when there were more logically possible

locations for the toy, but even the 6-year-olds' performance was quite poor with only a quarter of them doing this reliably.

Studies in which children are subject to physical uncertainty are rare. Gopnik and Rosati's (2001) report of 4- to 5- year-olds' ability to report reversals of the duck-rabbit ambiguous figure is relevant, although in this case there is no one true reality about which the child is ignorant. Another study in which children were exposed to physical, as opposed to epistemic, uncertainty is reported by Beck, Robinson, Carroll and Apperly (2005). The focus of this research was on children's counterfactual and future hypothetical reasoning, but a task was included in which chance determined whether a toy mouse would emerge from one of two possible outlets of a slide. Children placed mats to catch the mouse as in Sophian and Somerville's (1988) task described above. In Beck et al's (2005) game, however, at the time the child put mats in place it was still undetermined which way the mouse would fall: Uncertainty resided in the physical world and not just in the child's mind. Under these conditions, in this study, 3- and 4- year-old children spontaneously put out two mats on around one third of trials and 5- and 6- year-olds did so on two thirds. We cannot validly make a comparison with the very different study by Sophian and Somerville (1988) mentioned above, but the results are at least consistent with the possibility that children find it easier to specify possibilities under conditions of physical than epistemic uncertainty. In the experiments reported below we make comparisons under matched conditions.

We now consider the adult literature in which the two types of uncertainty have been compared by researchers interested in an apparently illogical difference in people's willingness to bet on uncertainties which are objectively identical, and its implications for

theories of decision making (e.g. Kahneman & Tversky, 1982). To return to the examples at the beginning, of a die yet to be thrown as contrasted with a die already thrown but hidden: Rothbart and Snyder (1970) asked undergraduates to place bets on their guessed outcome under these two conditions, and to indicate their confidence. Participants betting on a prediction (before they had thrown the die) bet more of the 10 pennies they had been given (median 5 pennies), and felt greater confidence in the correctness of their guess, than participants betting on a postdiction (after they had thrown the die, median 3 pennies). Although the probability of success is identical in the two conditions, participants bet more money when uncertainty was physical rather than epistemic. Rothbart and Snyder (1970) interpreted their results in terms of magical thinking: The prediction might magically have influenced the subsequent outcome.

However, similar findings occur when an illusion of magical influence seems implausible, for example a preference for betting on the rise or fall of a stock from tomorrow's Wall Street Journal rather than yesterday's (Heath & Tversky, 1991). Heath and Tversky (1991) present a series of experiments in support of their 'competence' hypothesis according to which under conditions of equal probability, people prefer to bet in a context in which they consider themselves competent or knowledgeable. People have this preference, these authors argue, because competence allows people to claim credit when they are right and its absence exposes people to blame when they are wrong. Of particular relevance to our experiments reported below is the suggestion by Heath and Tversky (1991) that people feel particularly incompetent, and so are particularly averse to betting, when the outcome is knowable in principle but unknown to them, that is with epistemic as opposed to physical uncertainty.

A final relevant study of adults' betting under uncertainty is by Chow and Sarin (2002) who report two experiments comparing participants' willingness to bet when they did not know the probability of success but the experimenter did, and when nobody knew. The mean amount of money participants were prepared to bet was higher when nobody knew the probability of success than when the experimenter knew. These authors interpret their results in terms of a 'comparative ignorance' hypothesis put forward by Fox and Tversky (1995): When people assume that information is available to others but not to them they are particularly intolerant of uncertainty, and when people assume information is unavailable to all, they are less intolerant. Chow and Sarin point out the subjective element in this classification of unknown *vs* unknowable information. For example, a lay person might assume that risks of death from certain causes are unknowable, whereas an actuary might know that probabilistic information is available and so might see themselves as relatively ignorant.

Whatever the explanation for the results with adult participants, their sensitivity to epistemic *vs* physical uncertainty is robust over a range of contexts. The implication of interest to us here is that people spontaneously represent their own perspective of ignorance *vis a vis* the more knowledgeable perspective of others or *vis a vis* their own possible perspective of knowledge, even when this is completely irrelevant to the task in hand. This raises an interesting developmental question: What might be the course of development of sensitivity to epistemic *vs* physical uncertainty?

The literatures on children’s handling of undecidability and ambiguity, summarized above, form one basis for making a prediction. According to these literatures, young children up to the age of around 7 years are particularly inclined to

make a single interpretation of limited information when it would be more appropriate to hedge their bets. At first sight, children's making of a single interpretation might be construed as similar to adults' willingness to place a bet under conditions of uncertainty, and children's acknowledgment of possibilities might be equated to adults' unwillingness to place a bet. If we draw this parallel, then on the basis of the adult literature reported above (adults bet higher amounts under conditions of physical than epistemic uncertainty) we would predict that insofar as children are sensitive to the distinction between physical and epistemic uncertainty, they will be more inclined to make a single interpretation (place a bet) under conditions of physical uncertainty, and more willing to specify possibilities (hedge their bets) under conditions of epistemic uncertainty. We label this Prediction 1.

However, drawing this parallel with the adult literature rests on either of two possible underlying assumptions which need to be explored before Prediction 1 can be deemed valid. One is that both children and adults, faced with uncertainty of outcome, ignore the fact that any particular outcome is uncertain and ignore other possibilities. We argue below this may well be the case for children faced with ambiguous input. For adults betting on an uncertain outcome, however, we can reject this characterization. The results of Rothbart and Snyder (1970), for example, show that although adults were more confident of the correctness of their prediction than their postdiction, they were still far from ‘completely confident’, implying awareness of the alternative possibility.

The alternative possible assumption underlying Prediction 1 is that, like adults in the betting task, children who make a single interpretation of limited information when they have the opportunity to acknowledge both possibilities, do really recognize both. For

some reason they choose to guess. This is plausible. Researchers of children's referential communication skills have pointed out that children may assume that speakers will provide clear, unambiguous messages which permit a single interpretation, and so are biased to make such an interpretation (e.g. Ackerman, 1981; Speer, 1984). Similar arguments are made in the literature on children's handling of undecidability (e.g. Acredolo & Horobin, 1987). It is also plausible that certain task conditions increase the likelihood that children will guess rather than hedge their bets, for example when the experimenter appears to expect them to make a single interpretation. It is not obvious why physical rather than epistemic uncertainty should prompt children to guess, but it is an empirical possibility that it does.

To summarize: If children who make a single interpretation when they have the opportunity to indicate possibilities are simply subject to a performative bias, and are really aware of alternative possibilities, then it seems appropriate to draw a parallel between adults' level of betting and children's making of single versus multiple interpretations. On this basis we can make Prediction 1: Insofar as children are sensitive to the distinction between physical and epistemic uncertainty, they will be more likely to make a single interpretation under physical uncertainty and more likely to acknowledge possibilities under epistemic uncertainty.

On the other hand, many researchers into children's handling of ambiguity and undecidability argue that making a single interpretation is not due *only* to a guessing bias. Rather, children can also suffer from a genuine inability to handle more than one possible outcome of a single event: The characterization which we rejected above for adults. For example, under conditions of epistemic uncertainty as used in the published literature,

children younger than around 7 years do not just make single interpretations of limited input but also evaluate the input as adequate (e.g. Beal & Flavell, 1982; Flavell, Speer, Green, & August, 1981; Robinson & Apperly, 2001; Robinson & Whittaker, 1987). They fail to explain why different people can make different interpretations of limited input (Carpendale & Chandler, 1996; Chandler, Hallet, & Sokol, 2002). These results suggest that the representational demands of holding alternative possibilities in mind are just too high for younger children (at least with epistemic uncertainty as investigated so far), and they use the representationally less demanding response of making a single interpretation, despite having initially noticed the alternative possibilities.

This line of argument leads us to make the opposite prediction, which we label Prediction 2: If the context encourages children to represent their own perspective of relative ignorance, the cognitive demands of so doing will make them more likely to respond in a representationally less demanding way to uncertainty, namely by making a single interpretation rather than by specifying possibilities. Conversely, when the child is in a position of physical uncertainty, with no additional representational demands, she will be most likely to make the demanding response of specifying possibilities rather than making a single interpretation. That is, insofar as children are sensitive to the distinction between epistemic and physical uncertainty, they will be more likely to specify possibilities under conditions of physical than epistemic uncertainty (Prediction 2).

Yet a third possibility, Prediction 3, is that children aged around 4 to 8 years, that is within the age range covered by the developmental literature summarized above, are insensitive to the variable of epistemic *vs* physical uncertainty and will be equally inclined or disinclined to specify possibilities in both types of circumstance. If this is the

case, then the developmental question will remain open, since it is clear that at some point on the route to adulthood, sensitivity does appear.

There is good reason to expect sensitivity to appear relatively late in development. Since Piaget (1926) examined children's egocentrism we have known that children are much less likely than adults to take into account differences between their own and other people's knowledge when it is important to do so. Adults are certainly not immune to errors of perspective taking (e.g. Birch & Bloom, 2003; Keysar, Barr, Balin & Brauner, 2000; Keysar & Henly, 2002; Keysar, Lin & Bar, 2003; Mitchell, Robinson, Isaacs & Nye, 1996), and under some conditions very young children do show sensitivity to knowledge differences (e.g. Baldwin & Moses, 1994; Baldwin et al., 1996; O'Neill & Topolovec, 2001). Nevertheless there is no doubt that children show a much greater difficulty than adults. Failure or inability to take into account another person's lesser knowledge appears to play an important role in, for example, children's failure to acknowledge others' false beliefs (e.g. Wimmer & Perner, 1983), in failures to communicate effectively (e.g. Asher & Wigfield, 1981;Whitehurst & Sonnenschein, 1981), and in failures to predict what knowledge another person will gain from limited information (e.g. Taylor, 1988).

In all the above tasks, child participants are at risk of ignoring the fact that they *know* something *relevant* about which another person is ignorant. In the circumstances we are interested in here, in contrast (when we know that adults unnecessarily represent irrelevant knowledge differences), the child is *ignorant* of something which they could know, and it is task *irrelevant* whether or not the child’s ignorance is shared. Surely we might expect it to be relatively late in development that children spontaneously represent

irrelevant knowledge differences? We might also expect it to be more difficult to take into account differences in perspective when the child is in the position of ignorance rather than knowledge, since there is no content to represent when one doesn't know something. Birch and Bloom (2003), who argue that children have difficulty inhibiting the content of their own knowledge base when it would be appropriate to do so in a perspective-taking task, also argue that there is no equivalent 'curse of ignorance' since there is nothing to inhibit when one is ignorant. There are several grounds, then, for expecting that sensitivity to the difference between physical and epistemic uncertainty would be a relatively late development, emerging well after the age of 4-5 years when children come to acknowledge false belief, and probably after 7-8 years when they come to acknowledge different interpretations of ambiguous input.

We report three experiments to test our three predictions. In all three experiments children were asked to specify possibilities under conditions of certainty (a single outcome could be predicted with confidence) and uncertainty (two outcomes were equally likely). As in Sophian and Somerville's (1988) task, and in Beck et al (2005), children placed a physical marker to indicate the possible outcomes, for example mats to catch a falling block in Experiment 1, or food to keep a hidden pet in good health in Experiment 2. By asking children to specify possibilities we avoided any superficial bias against admitting "don't know": Children showed what they *did* know on the basis of the limited information available. On the other hand, by asking children to place two physical markers for a single event, we imposed a strict criterion of simultaneous rather than successive consideration of possibilities.

In each experiment we compared children's responses under conditions of physical and epistemic uncertainty. Did they respond differently under the two conditions, indicating sensitivity to their own relative ignorance (contra Prediction 3)? If so, were the findings in line with Prediction 1 or Prediction 2? That is, do children show the same direction of difference as adults, or the opposite?

We aimed to minimize any general bias towards guessing when there were two possible outcomes. In Experiment 1 we encouraged (and children enjoyed) successful catching of a block. In Experiments 2 and 3, children risked an imaginary pet going hungry if they guessed which of two containers it might be in. However, if there was any residual general bias towards guessing, then the matching of tasks ensured that this was the same under conditions of epistemic and physical uncertainty.

Experiment 1

We compared children's responses to physical uncertainty (on *unknowable* trials), when it was as yet undetermined which of two outcomes would happen, with their responses to epistemic uncertainty (on *unknown* trials), when the experimenter knew what would happen but the child did not because the relevant clue was hidden from view.

Method

Participants. There were 29 younger children (12 girls) aged 4;5 – 5;4, M age = 4;11, and 30 older children (14 girls) aged 5;5 – 6;4, M = 5;11, from a middle class nursery in Birmingham UK, who had English as their first language.

Materials. We used a box whose front wall was approximately 40 cm square, and which bore three vertical stripes colored orange, black and green. Three doors were cut in the top of this wall, one in each stripe. Behind the doors was a horizontal shelf, wide

enough to hold a small plastic building block, invisible when the box was viewed from the front. In addition we used two trays approx. 10cm x 10cm, lined with cotton wool, each of which could be placed at ground level beneath one of the doors. Two tall stiff paper bags (of the kind used to hold gift wine bottles), one colored orange and green and the other black, were used to hold plastic building blocks. The tall narrow shape of the bags meant that when the experimenter put an arm in one, neither he nor the child could see which block was being picked. The orange and green bag contained 10 orange and 10 green blocks, and the black bag contained 10 black blocks. Two blue blocks were used for the warm-up trials.

Procedure. The child was shown the box with the shelf and the doors, and asked to name the colors of the three stripes. The experimenter (D. Carroll) then showed the two bags with their building block contents, and the child identified the colors and noted the match between the colors of the bags and their block contents. On warm up trials the child was shown how to place a tray beneath a door to catch a block, was shown and told that a block always came through its matching door, and was explicitly shown and told that when she did not know which of two doors the block was behind she needed to place two trays to catch the block.

Each child then had four experimental trials, on two of which it was necessary to put out two trays (reality *unknown* and reality *unknowable* trials), and on two of which it was sufficient to put out one tray (*shown* and *black* trials*)*. On *unknowable* trials the experimenter said he was going pick a block out of the orange and green bag, but before he picked it the child was asked to put out trays to make sure the block was caught. ‘Trays’ in the plural was used so that if anything we biased children to place two trays

rather than a single one. A child who put out only one tray was prompted “Could it (the block) go anywhere else?” and was allowed to add or move a tray if she wished. The experimenter then pushed the block through the door and commented that the child had or hadn’t caught it.

On *unknown* trials the procedure was similar, except that the experimenter picked a block from the green and orange bag *before* the child put out trays, looked at the block and placed it on the ledge behind the matching door without letting the child see, and only then asked the child to place trays, with a prompt as on unknowable trials if necessary. When the experimenter placed the block on the ledge he moved his hand behind all three doors so that the child could not infer by watching his hand where the block was.

On *shown* and *black* trials it was sufficient to place one tray, since the child could predict exactly which door the block would come through. On shown trials the experimenter said he would take a block from the orange and green bag, did so, and showed it to the child. Then he placed it on the shelf behind the appropriate door. The child was invited to put out trays. On black trials the experimenter said he was going to take a block from the black bag, and asked the child to put out trays *before* he put his arm in the bag. Hence the shown trials were similar to reality unknown in that the block was in place before the child placed trays. The black trials were similar to the reality unknowable trials in that the child placed trays before the block was taken from its bag.

Each child had one trial of each type (unknown, unknowable, shown, black), presented in 4 predetermined orders. Constraints on the orders were that the pattern of

sufficient tray placements was 1, 2, 2, 1 or 2, 1, 1, 2. The four orders were: Unknowable (L), Black (B), Shown (S), Unknown (N); NSBL; SLNB; BNLS.

Results and Discussion

On each trial children received a score of 1 if they spontaneously put out the sufficient number of trays in the correct location (1 on shown and black trials, 2 on unknown and unknowable trials), and a score of 0 if they did not (strict coding).

A second, lenient scoring system included responses following any prompt on determined and undetermined trials: Children gained a score of 1 if they passed under the strict coding above, or if they added a second tray appropriately after the prompt so that both doors were then covered.

We began by examining performance across the four types of trial to judge whether children treated the game as intended. Table 1 shows the frequencies of scores for each trial type. As shown in Table 1, children nearly always put out only one tray (gaining a pass) on shown trials when that was sufficient because they had seen the orange or green block before it was placed on the shelf behind the matching door. On black trials, when the child had not seen the block but could infer that it was black, there were 10 occasions when the child placed a tray under the black door and unnecessarily but not wrongly placed a second tray under another door (perhaps because they were invited to place ‘trays’ rather than ‘a tray’). On one trial a child wrongly failed to place a tray under the black door. Despite these responses, and despite the biasing prompt, on the great majority of trials children placed only one tray when that was sufficient to ensure that they caught the block.

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We can therefore go on to examine performance on trials when one tray was not sufficient: Unknown and unknowable trials. On both these trial types the child knew only that the block was either orange or green. On unknowable trials the particular block was yet to be chosen when the child placed trays**,** and on unknown trials the block was already in place on the shelf but hidden from the child. We compared performance on these trials using McNemar tests. Using the strict coding, 9 4-5 year olds passed the unknowable trial but not the unknown trial, and 1 showed the opposite pattern. This difference was significant, N=31, p=0.021. The same significant difference was found for the 5-6 year olds: 14 children passed unknowable but not unknown and 1 shown the opposite pattern N=30, p=0.001. The difference between trials remained for the younger group when the liberal coding was used, 7 children passing unknowable but not unknown, none showed the opposite pattern, N=31, p=0.016, but failed to reach significance for the older group, although the pattern was the same. 9 children passed unknowable and not unknown, 2 showed the opposite pattern, N=30, p=0.065. Age differences were not significant: Children in both age groups showed good performance on the unknowable trials, but performed relatively poorly on the unknown trials.

Children more readily realized that one tray was insufficient when a block was yet to be selected, than when one was already in place behind one of the doors. Even the 4- to 5-year-olds were able to cover both possibilities on unknowable trials, but even 5- to 6-year-olds often failed to do so on unknown trials. This pattern of results goes against Predictions 1 and 3, but is in line with Prediction 2. According to Prediction 2, children

this age do attempt spontaneously to represent their own position of ignorance under conditions of epistemic uncertainty, this is representationally demanding for them, and so they use a less mature response of making a single interpretation. Under conditions of physical uncertainty there are no additional representational demands and children can acknowledge both possibilities.

Experiment 2

In this experiment we again investigated children's willingness to acknowledge simultaneously two possible outcomes of a single event, but this time the children acted on behalf of another who shared their own state of ignorance. One possibility is that in Experiment 1, even though children did not have to make a "don't know" judgment, they were unwilling to admit their own uncertainty by placing two physical markers for a single event. If so, acting on behalf of somebody else should minimize any bias of this kind. We again compared children's judgments under two conditions. In one, similar but not identical to the reality unknown trials in Experiment 1, the event in question had already happened: An imaginary pet was in one of two boxes but neither child nor story protagonist knew which. In the second condition, similar but not identical to the reality unknowable trials in Experiment 1, the event in question was yet to happen: An imaginary pet was not yet in either box. We were interested in whether or not children found it more difficult to acknowledge the two possibilities when the pet was already in one of the boxes.

In Experiment 1 the contrast between the reality unknown and reality unknowable trials was objectively clear-cut, although we did not know in advance whether children would represent the two trial types differently. The observed difference in difficulty

suggests that they did. In Experiment 2, the situation was less clear-cut. On all experimental trials the experimenter read out an ambiguous message which had two possible interpretations. Presumably the writer of the message knew the intended meaning and on those grounds children might represent the situation as one in which reality was unknown rather than unknowable, uncertainty epistemic rather than physical. On the other hand, the writer of the message was (deliberately) a remote figure who lacked salience, and the experimenter appeared to share the child's ignorance. We expected therefore that children would treat the intended meaning of the message as unknowable rather than unknown, so that we could examine the variable of interest, namely whether or not there was already an imaginary pet in one of the boxes. When the ambiguous message indicated that a pet was already in one of the boxes, we expected it to be salient that reality was unknown rather than unknowable: Uncertainty would be epistemic. In contrast, when the boxes were still empty and the ambiguous message indicated that a pet was to occupy one of them in the future, we expected children to be more likely to assume reality was unknowable: Uncertainty would be physical. When children represented the task as one in which reality was unknown, they could take into account the fact that they (and the story protagonist) had a particular perspective of ignorance, whereas when they represented the task as one in which reality was unknowable, individual perspectives could be ignored.

Method

The experimenter (M. Rowley) described a scenario about Mr. Jones who works in a pet shop which contains a number of boxes of different colors and sizes for housing and transporting pets. The child's task was to act on behalf of Mr. Jones, placing food in

sealed boxes which could contain animals to be transported to another shop, or putting locks on boxes so the animal could not escape. The child always shared the same state of knowledge or ignorance as Mr Jones.

Participants. We included children similar in age to the older age group in Experiment 1: 30 children (18 girls) aged 5;9 - 6;9, M age = 6;2. All attended a primary school in Staffordshire, UK, and had English as their first language.

Procedure. The experimenter explained the scenario: "This is Mr. Jones and Mr. Jones works in a pet shop. There are lots of boxes in the pet shop that the pet shop owner uses to send animals to other shops. The owner of the pet shop is always working at another shop a long way away so he leaves messages for Mr. Jones telling him what to do. Every week Mr. Jones has to send some animals to the other shop. He also has to send plenty of empty boxes so that the other shop always has somewhere to keep their animals." Each child had two experimental trials involving ambiguous messages, one with reality *unknown* and one with reality *unknowable,* with order counterbalanced between children. In addition, each child had two unambiguous control trials on which the message contained sufficient information for her to know the true state of affairs: Reality was known. One of these unambiguous trials used the materials of the unknown task, and the other used the materials of the unknowable task. The unambiguous control trials immediately preceded their matching ambiguous trial in order to give children any benefit of experiencing the contrast between ambiguous and unambiguous messages.

In the *unknown* task the child was shown a set of three boxes, for example one large red box, one large blue box and one small red box. The experimenter demonstrated the placing of locks on the boxes to make sure an animal did not escape, or the placing of

food containers to make sure any animal inside did not go hungry on its journey. The experimenter read out an ambiguous message from the owner, for example “The mouse is in the red box.” The experimenter explained the response options, for example putting food in the red box only, the blue box only, or both boxes. The child was then asked “Show me where Mr Jones will put food to make sure the [mouse / hamster] has food to eat”, and to explain her response. The appropriate response was to put food in both possible boxes. After children had responded they were offered an alternative response: Children who had put food in only one box were asked “What about putting food in both boxes, would that be OK?” Children who spontaneously put food in both boxes were asked whether it was OK to put food in only one. Finally children were asked to recall what the message was on that trial.

On the matching control trial using the same materials the message was unambiguous, for example “The hamster is in the blue box”. It was sufficient to put food in one box. After the child had responded the experimenter offered the child an alternative, referring to both boxes. There was a final recall check as for the ambiguous message.

In the *unknowable* task the experimenter explained that customers could bring back unwanted pets. They might bring back a grown-up pet, which could go in any empty box, or a baby pet, which must go in a warm box. The child was shown special boxes for baby birds which contained a perch and a bell, and for baby mice which contained a wheel. These boxes for baby pets could be warmed up in advance by turning on a switch. As on the unknown trials, the experimenter read out an ambiguous message from the owner, which left it unclear whether a baby mouse or a baby bird was going to come:

"…..someone is going to bring back a baby pet". The child was asked "Show me what Mr Jones will do to make sure there is a warm box ready". The appropriate action was to put the switches on for both baby pet boxes. As on unknown trials, children were offered an alternative response and invited to accept or reject it with a reason, and finally recalled the message.

On the matching unambiguous control trial using the same materials, the message stated whether a baby mouse or bird was due to be returned, so it was sufficient to put the switch on for one box of the correct type.

Results and Discussion

Recall of the messages was near ceiling: 2 children made errors on one trial only. Concerning selection of food or locks for the boxes, children were scored as passing an unambiguous control trial if they acted only on the location referred to in the message either spontaneously or after the prompt, and gave an adequate reason which indicated that they knew the content of the message, for example "Because there's a mouse in the box" or "The message said mouse." As expected, children performed well on the unambiguous trials, acting only on the box identified in the message: 7 children out of 30 made one or more errors, in every case by responding to two boxes (e.g. large yellow and large green) rather than just the one referred to (yellow). This response is not strictly wrong given the scenario, since there was no penalty for playing safe and covering additional possibilities. Nevertheless, interpretation of the results depends on the majority of children not playing safe when the message was unambiguous, as was the case.

Children were scored as passing an ambiguous experimental trial (whether in the unknown or the unknowable task) if they acted on both possible locations either

spontaneously or after the prompt, and gave an adequate reason (either before or after the prompt) which referred to the fact that the animal could be in either location, such as "We don't know which one its in." Hence the scoring in this experiment was similar to the lenient scoring in Experiment 1, except that children had the additional demand of giving an adequate justification of their response. Table 2 shows the frequency of correct and incorrect responses in the unknown and unknowable tasks.

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Insert Table 2 near here

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As shown in Table 2, children performed better in the unknowable task (70% correct) than in the unknown task (40% correct). Children who passed only one task were more likely to pass the unknowable than the unknown task: binomial test $p < .001$. Five- to 6-year-olds found it easier to acknowledge both possibilities simultaneously when the event was yet to happen compared with when the event had already happened but was unknown to the child.

Results are consistent with those of Experiment 1, and again in line with Prediction 2 and against Predictions 1 and 3. Here we extend the finding to children's acting on behalf of a story protagonist, and to conditions under which they were expected to give a verbal justification of their response rather than just respond appropriately. Although children could in principle have considered their own and Mr Jones' perspectives of ignorance *vis a vis* the intended meaning of the message in both trial types, they seemed not to do so. Rather, as expected, their own perspective of ignorance seemed to be salient only when the imaginary pet was already in one of the boxes.

One possible weakness of the procedure in Experiment 2 is that the unknown and unknowable tasks did not use the same materials, and it could be that for some reason children just found it more inviting to switch on both switches for a baby pet of unknown identity, than to place food in both boxes for a pet in an unknown location. This seems unlikely, particularly given the high frequency of selecting a single switch on unambiguous trials using the materials of the unknowable task. Nevertheless as a further check in Experiment 3 we created a very close match between reality unknown and unknowable tasks: Only the tense of the verb in Mr Jones' message differed.

In addition, in Experiment 3 we changed the response measure again to explore the generality of the difference in difficulty between unknown and unknowable conditions. In Experiment 1 children acted on their own behalf; in Experiment 2 children acted on behalf of a protagonist who shared their own perspective of ignorance; in Experiment 3, children gave a mental state judgement for the protagonist (who shared their perspective of ignorance) by indicating what Mr Jones *knew* about where the pet was.

Experiment 3

In the final experiment, we used the same pet shop scenario as in Experiment 2, but we included trials on which children were asked to make judgements about Mr Jones' knowledge rather than his behaviour. For these trials we used a task similar to the reality unknown task of Experiment 2, and created a reality unknowable version. Instead of acting on behalf of Mr Jones, children selected a thought bubble to indicate what Mr Jones knew about where the pet was (on reality unknown trials), or what he knew about where the pet would be (on reality unknowable trials). In addition, each child had one

ambiguous reality unknown trial exactly the same as in Experiment 2's reality unknown task, with a matching unambiguous control message: We now label these *action* trials to differentiate them from the thought bubble trials. Given the rather poor performance of the 6-year-olds in the reality unknown task in Experiment 2 (40% correct), in Experiment 3 we included an older age group, 7- to 8- year-olds.

The judgments on action trials (as used in Experiment 2) and the new thought bubble trials were importantly different. When the message was ambiguous, children were expected to indicate using a thought bubble that Mr. Jones knew that the pet was *either* in location 1 *or* in location 2, but that his appropriate action was to place food *both* in location 1 *and* in location 2. We cannot assume that children would find it equally easy or difficult to acknowledge the two possibilities in these two different ways, even though the underlying problem was the same. Should the thought bubble judgments prove to be more difficult, we would not expect this to be due merely to superficial task demands: Previous research (Wellman, Hollander & Schult, 1996) has shown that children very much younger than the participants in this experiment can handle thought bubble tasks. In addition, the linguistic concept 'either…or' is one of a group of early acquired linguistic concepts included as sub-test items in The Clinical Evaluation of Language Fundamentals – Preschool Test (CELF- Preschool; Wiig, Secord & Semel, 1991). In the test, designed to assess receptive and expressive language ability, 3-year-olds are expected to be able to respond correctly to a direction to select a picture of 'either A …or B'. We therefore expected that the 5- to 6-year-olds in our sample to have no difficulty with "either… or," or with selecting thought bubbles to indicate what the protagonist knew.

Participants. 40 children (16 girls) aged 5; 9 - 6; 5, M age = 6; 2, and 40 children (21 girls) aged 7; 9 - 8; 7, M = 8; 1. Children attended two primary schools in Staffordshire, UK, and had English as their first language.

Procedure. Each child had four trials: Two action trials (one reality unknown trial and one unambiguous control trial using the same materials) which were exactly the same as in Experiment 2, and two thought bubble trials. Half the children received a thought bubble trial of the reality unknown type, and a matched unambiguous control trial. The other half of the children half received a thought bubble trials of the reality unknowable type, and a matched unambiguous control trial. We did not include action unknowable trials in order to maintain a close match between trial types, as will become clearer below.

On the *thought bubble* trials with reality *unknown* and reality *unknowable,* the experimenter (M. Rowley) read out an ambiguous message from Mr Jones as in Experiment 2. For example, "The rabbit is in the large box" (unknown) or "The rabbit is going to be in the large box" (unknowable) could refer either to the large pink or the large white box. Instead of acting on the boxes, the child was asked to choose one picture from a set of three pictures with thought bubbles to illustrate what Mr Jones now knew about the pet's location. One picture showed Mr Jones with a thought bubble containing the large pink box, a second picture showed him with a thought bubble containing the large white box, and a third picture showed him with a thought bubble containing both the pink and the white boxes with the word 'OR' between and a large question mark. The experimenter explained what each picture meant, and asked the child to select one and give a reason. As in Experiment 2, children were then offered an alternative response. For

example a child who had chosen the option depicting ‘either box’ was asked "What about choosing the picture that shows he knows the rabbit is in the pink box, would that be OK?" Finally children were asked to recall what the message was on that trial. Unambiguous control trials were similar, referring either to a single current location, or to a single future location.

Result and Discussion.

As in Experiment 2, recall of the messages was good on all trial types. Performance on unambiguous control trials was also good: On unambiguous action trials, 2 children made errors and on unambiguous thought bubble trials, no child made an error.

In the reality unknown action task we used the same criteria for scoring responses as correct or incorrect as in Experiment 2. Equivalent criteria were used for the thought bubble reality unknown and unknowable trials: Children passed if they selected the dual option thought bubble either spontaneously or after the prompt, and gave a reason which referred to the fact that the pet could be in either location.

On *reality unknown action* trials, 12 out of 40 5- to 6-year-olds (30%) passed, as did 27 out of 40 (67%) 7- to 8-year-olds. As expected, older children performed significantly better than younger ones: χ^2 (79) = 11.26, p = < .001, although performance was not at ceiling even amongst the older children.

On the *reality unknown thought bubble* trials, 3/20 (15%) 5- to 6-year-olds passed, as did 9/20 (45%) 7- to 8-year-olds. Although the frequencies of correct responses suggest that performance was poorer than on reality unknown action trials, the difference failed to reach significance: Combining across the age groups, 5 children

passed the action trials but failed thought bubble, compared with none who showed the reverse pattern.

On *reality unknowable thought bubble* trials 2/20 (10%) 5- to 6-year-olds responded correctly, as did 16/20 (80%) 7- to 8-year-olds. The older children, but not the younger, performed better on the reality unknowable thought bubble trials than on the reality unknown thought bubble trials: χ^2 (39) = 5.23, p = < .02 (7-8 yrs); χ^2 (39) = .23, ns (5-6 yrs).

The fact that the 5- to 6-year-olds showed no difference in difficulty between the reality unknown and unknowable thought bubble trials could be because even the unknowable thought bubble judgements were still too difficult for them. Alternatively, they may have had a more superficial difficulty with the thought bubble procedure, perhaps finding it hard to understand what the dual possibility thought bubble represented. We argued above that this latter suggestion was unlikely. For our purposes here, the important result is that for the older children at least, we find differentiation between reality unknown and unknowable trials, which map onto epistemic and physical uncertainty. As in Experiments 1 and 2, results are in line with Prediction 2 and against Predictions 1 and 3.

Final Discussion and Conclusions

The results of the three experiments reported here provide clear evidence that children aged between 4 and 8 years differentiate conditions of epistemic uncertainty from physical uncertainty. Prediction 3, that children this age are insensitive to the distinction, can be rejected. Children, like adults, appear spontaneously to represent their own perspective of ignorance even when it is completely irrelevant to the task in hand.

Prediction 1 can also be rejected. Prediction 1 assumed that children who make a single interpretation are really aware of possibilities, and that making a single interpretation is similar to placing a high bet in the adult tasks, while acknowledging both possibilities is similar to placing a low bet in the adult tasks. Adults place higher bets under conditions of physical than epistemic uncertainty. In contrast, our child participants were more likely to make single interpretations under conditions of epistemic than physical uncertainty, contrary to Prediction 1.

The results of all three experiments are in line with Prediction 2. Prediction 2 rested on the assumption that young children have difficulty meeting the representational demands of acknowledging possibilities. Epistemic uncertainty imposes additional representational demands: The child represents her own perspective of ignorance. If the child spontaneously decides to do this, she will be less likely to be able also to manage the demands of acknowledging possibilities and will be more likely to make a single interpretation. This account fits the results with three different response measures: The child's own action (Experiment 1), action on behalf of a story protagonist who shared the child's perspective of ignorance (Experiment 2), and mental state judgements on behalf of a story protagonist (Experiment 3). Discrimination between the two types of uncertainty was apparent even for 4-year-olds in Experiment 1. In the thought bubble task of Experiment 3 children had to indicate that the outcome could be either X or Y instead of marking both X and Y as in Experiments 1 and 2. In Experiment 3, it was only the 7- to 8-year-olds who differentiated between types of uncertainty. Not surprisingly, the particular task demands are relevant to whether or not children represent their own perspective of ignorance under conditions of epistemic uncertainty.

The procedures used in the three experiments differed not only in the response measures, but in the manner in which epistemic uncertainty was conveyed. In Experiment 1, the game was controlled by the experimenter and on reality unknown trials the experimenter knew which door the block was going to fall through. There was a clear difference in knowledge between child and experimenter. This difference in knowledge might have been sufficient for children to represent their perspective of ignorance, but it was not a necessary feature for them so to do. In Experiments 2 and 3, the child was given no indication that the experimenter knew the location of the imaginary pet; the experimenter's role was simply to read out the messages from the pet shop owner. In this case, epistemic rather than physical uncertainty arose because it was salient that the child *could* easily know which box contained the imaginary pet, rather than because somebody else did know. This could also have been the relevant variable in Experiment 1, since the child could easily have looked behind the doors to see where the block was hidden. Hence the variable common across all three experiments was the salient presence of a hidden object which the child could easily access in principle. From the results so far, however, we cannot specify the limits of the set of circumstances that prompt children to represent their own perspective of ignorance.

That they do so at all seems puzzling in the light of the published literature on children's failures to take into account their own relative knowledge when it is important to do so: The rationale for Prediction 3. As summarized in the introduction, young children often fail take into account the fact that they know something about which another person is ignorant, and this can contribute to errors in, for example, standard false belief tasks. This phenomenon has been labelled a 'realist bias' (Mitchell, 1996), or a

'curse of knowledge' (Birch & Bloom, 2003). However, it is important to realise that in our tasks we have shown no more than sensitivity to the variable of relative ignorance: Children responded *differently* under conditions of epistemic and physical uncertainty. In contrast, research on children's handling of relative knowledge examines their skill at responding *correctly*, for example when speaking to a listener who knows less than they do, or predicting the action of a protagonist who is relatively ignorant. It is quite possible to respond differently under different conditions, showing sensitivity to the variable in question, despite showing a high level of errors in any one condition.

Despite this important proviso, our results perhaps suggest a need to take a different slant on children's 'realist bias' or 'curse of knowledge'. First, contrary to Birch and Bloom (2003), such errors are not specific to circumstances when the child is the more knowledgeable. Second, realist errors should not be seen as a sign of insensitivity to differences in perspective. Rather, if our account is correct, children as young as 4 years are *particularly* sensitive to the fact that they have an individual perspective on the world, even when this is task-irrelevant. Representing their perspective of ignorance appeared to take precedence over representing the possible outcomes of the task in hand.

Finally, our results have potentially important implications for research on children's developing understanding of the mind as an active interpreter of information. It is well documented that although children around the age of 4 years are normally willing to acknowledge false beliefs, it is not until they are several years older that they accept that the very same input can be interpreted differently by different people. For example, in one task used by Carpendale & Chandler (1996), a coin was hidden under one of three blocks, and the child participant heard a message that narrowed the possibilities down to

two. Two story protagonists each made one of the possible interpretations, and the child was asked to explain why they made different interpretations. Five- to 6-year-olds had difficulty with this, but by 7 to 8 years many children accepted the legitimacy of the protagonists' different interpretations and explained them in terms of ambiguity in the message. Success in this kind of task is taken to be evidence that the child participant has come to construe the mind as an interpreter of information, and has begun to understand the mark that individual minds can place on incoming information. The evidence suggests that this understanding continues to develop through adolescence and into adulthood, with the adoption of increasingly demanding epistemic stances (Kuhn, 2000).

The tasks used in work on interpretive theory of mind involve epistemic rather than physical uncertainty. In the hidden coin task above, the child participant could easily have known where the coin was hidden; she was in a position of relative ignorance. Our results suggest that under such conditions children find it relatively difficult to represent the possibilities *for themselves*. Poor performance in theory of mind research involving such tasks might be due not to a failure to understand the mind as an interpreter, but rather to difficulty holding in mind both possible interpretations. If children were faced with two protagonists who made different interpretations under conditions of physical, rather than epistemic, uncertainty, they might much more readily explain why this was legitimate. What appears in the literature to be an immature conception of the mind may really arise from children's difficulty representing their own position of ignorance under conditions of epistemic uncertainty.

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Table 1. Experiment 1: Frequency of correct answers by age group and trial type.

		Performance strict coding (lenient coding, where included, in brackets)	
		fail	pass
4-5 yrs. N=31	Unknowable	11 (1)	20 (30)
	Unknown	19 (8)	12 (23)
	Black	7	24
	Shown	1	30
5-6 yrs. N=30	Unknowable	4 (2)	26 (28)
	Unknown	17 (9)	13 (21)
	Black	4	26
	Shown	1	29

Table 2. Experiment 2: Frequencies of pass and fail responses to ambiguous messages in reality unknown and unknowable tasks.

Unknowable	Unknown	
	Pass	Fail
Pass	11	10
Fail	1	8