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Imagining What Might Be: Why Children Under-estimate Uncertainty.

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Abstract

Children's well-documented tendency to behave as if they know more than they do about uncertain events is reduced under two conditions: When the outcome of a chance event has yet to be determined, and when one unknown outcome has occurred but is difficult to imagine. In Experiment 1, in line with published findings, 5- and 6-year-olds (N = 69) preferred to guess the unknown location of a known object when the object was in place rather than before its location had been determined. There was no such preference when the object's identity was unknown. In Experiment 2, 29 5- and 6-year-olds were more likely correctly to mark both possible locations when an already hidden object's identity was unknown rather than known. We conclude that children's vivid imaginations can lead them to under-estimate uncertainty, in a similar way to imagination inflation or fluency effects in adults.

Imagining What Might Be: Why Children Under-estimate Uncertainty.

Young children have more difficulty responding appropriately to uncertainty than adults do. They make single interpretations based on insufficient information and claim that they know what is intended when a message is ambiguous and has multiple interpretations (e.g. Beck & Robinson, 2001; Ironsmith & Whitehurst, 1978; Taylor, 1988). This apparently overconfident behavior is seen even when implicit measures (e.g. response latencies, eye movements) indicate that children are taking into account the different possibilities (e.g. Plumert, 1996; Nilsen, Graham, Smith, & Chambers, 2008). The problem is not simply that children fail to notice the alternative possibilities.

Until recently, studies had only examined children's responses to uncertainty in situations when there was a reality about which the participant was ignorant (epistemic uncertainty). However, new studies showed that children's difficulties were reduced when uncertainty existed because the outcome had yet to be determined (physical uncertainty. Robinson, Rowley, Beck, Carroll, & Apperly, 2006). In a game where children had to catch an object that would fall from one of two doors, 5- and 6-year-olds were more likely to place two mats, thus ensuring that the object was caught, when the object had yet to be hidden behind a door (physical uncertainty) than when it was already in place (epistemic uncertainty). Further evidence comes from a study in which children played a guessing game (Robinson, Pendle, Rowley, Beck, & McColgan, 2009). The task was to guess what number would come up on a die that was thrown under a cup, so that no one could see the outcome. Children chose to guess before or after the outcome was determined (but remained unknown). 95% of 5- and 6-year-olds chose to guess after the die had been thrown. This is what we would

expect if children find it more difficult to think about the multiple possibilities when the uncertainty is epistemic rather than physical. Both epistemic and physical uncertainty lead to subjective ignorance for the individual, but they result from different states of the external world. That children treat events involving epistemic and physical uncertainty differently suggests that the state of the external world affects how children think about uncertainty. The evidence converges on the possibility that children are more likely to represent only one outcome under epistemic uncertainty: they tend to place only one mat to catch a block that could fall from one of two places and they behave as if they can be confident in the outcome.

Despite now knowing that children are more likely to respond appropriately to one type of uncertainty compared to another, we do not know why this difference occurs. The possibility to be examined here is that once the object is behind the door or the die has been thrown children might imagine one of the possible outcomes: The object in a possible location or the number on the die under the cup. We know that young children have rich imaginative abilities. They enjoy pretence and explore sophisticated fictional worlds (e.g. Freidman & Leslie, 2007; Rakoczy, 2008; Skolnick & Bloom, 2006). Being imaginative has broad positive consequences for children's cognition (Harris, 2000): Children with imaginary companions perform better on various cognitive tasks compared to their peers without such friends (e.g. Roby & Kidd, 2008; Taylor & Carlson, 1997). Several papers have shown that although 4-year-olds find counterfactual syllogistic reasoning tasks very difficult, their performance improves when they are encouraged to use their imagination (Dias & Harris, 1988; 1990; Richards & Sanderson, 1999).

Could children, in imagining our scenarios, be drawn to imagine they know the currently unknown reality (which door the block is behind or the number that has

come up on the hidden die)? Children's sophisticated imagination may make it particularly easy for them to imagine one of the possible outcomes of a chance event once it has occurred. This act of vividly imagining one possible outcome may result in children behaving as if this is this actual outcome. This imagination account suggests that in the Doors game, for example, the ease with which children can generate a vivid image of the object in place under epistemic uncertainty may lead them to confuse this with knowledge about its location. Similar metacognitive errors based on the ease with which one can bring something to mind, or fluency, are well known in the adult literature (see Alter & Oppenheimer, 2009 and Schwartz, Benjamin, & Bjork, 1997 for reviews). Physical uncertainty may not cause the same problems, because the outcome has not yet occurred. So the child is not led to imagine a completed outcome and imagine this to be the true outcome. Mistaking an imagined outcome for the true one could also lead to the preference for guessing under epistemic uncertainty observed in studies such as the Die game (Robinson et al., 2009). During the practice trials in this game, children experienced guessing under epistemic and physical uncertainty. If they vividly imagined the outcome under epistemic uncertainty but not under physical uncertainty, they may feel greater confidence than when they guessed under the former. This could plausibly have led to the preference for guessing under epistemic uncertainty.

We tested whether the imaginability of the outcome affected children's handling of uncertainty using a version of the Doors game (Robinson et al., 2006). We manipulated the ease of imagining the outcome: in one condition (Specified) children knew what object was placed behind the door, in the new condition (Unspecified) the child did not know what the object was. Being ignorant about the

identity of the object should make it more difficult to imagine the object in place. Would this affect children's handling of uncertainty?

Previous studies of children's responses to physical and epistemic uncertainty tested children from 4 to 8 years of age. Children at all ages prefer to guess under epistemic uncertainty compared with physical (Harris, Rowley, Beck, Robinson & McColgan, in press; Robinson et al., 2009), but children's success marking multiple possibilities improves with age (Robinson et al., 2006). Our aim in this experiment was specifically to investigate why children behave more confidently under epistemic uncertainty. We chose to test just one age group (5- to 6-year-olds) to prove the point in principle. We return to discuss developmental implications of our findings in the General Discussion.

Experiment 1

In Experiment 1, children indicated their preference to guess under epistemic or physical uncertainty (see Robinson et al., 2009). The imagination account predicted a preference for guessing under epistemic uncertainty rather than physical uncertainty in the Specified condition, but no preference at all in the Unspecified condition, as children should be less likely to imagine an unknown object in place in the epistemic version.

Method

Participants. Sixty-one children (29 girls; mean age 6 years 1 month (6;1), range 5;6 – 6;6) participated. They were recruited from and tested at a school serving a working and middle class population in the U.K..

Materials. Our apparatus was modeled on that used by Robinson et al. (2006). A large cardboard screen (approx. 40cm^2) was divided into three vertical sections colored red, white, and green. In each section a flap covered a door (approx 2cm

squared), behind which there was a shelf. The shelf was cushioned so that auditory cues would not reveal the location of the hidden items. We also used a purple mat (approx. 12 cm^2), a large die (approx. 2 cm cubed, with two sides colored each of red, white, and green), orange blocks (approx. 1.5cm cubed), yellow pom poms (approx 1.5cm in diameter) in a transparent box (10cm cubed), and a collection of small objects (e.g. ball, plastic cat) in an opaque box (10cm cubed). During the task we referred to the die as a "dice" as this word is typically used by British children to indicate the singular.

Procedure. Children were tested individually. Each played under both specified and unspecified conditions with the order alternated between children. The experimenter began by demonstrating the game, using a type of object that would not feature again in the procedure: She threw the die in view of the child, and explained that the color shown on the top face determined which colored door the block would be pushed through. The block was put in place behind the correct door and children were directed to put out the mat to catch the block, which was then caught successfully.

Experimental Trials. In each condition, Specified and Unspecified, there were two practice trials (one epistemic and one physical) and one test trial. The order in which the practice trials were played and the corresponding order in which these trials were referred to in the test trial were counterbalanced between children.

In the Specified Condition, the experimenter put the transparent box containing the pom poms on the table and told children that they would be playing with "this box with pom poms in it". On the physical practice trial the experimenter took a pom pom from the box and said, "This time you're going to guess before I've thrown the dice. Can you guess which door the pom pom is going to fall from? Put the

mat under the door you think the pom pom is going to fall from". Once children had indicated their guess with the mat, the experimenter threw the die out of the child's view behind the screen and placed the pom pom behind one of the doors. On both practice trials the experimenter ensured that the child's guess was wrong so that feedback on the epistemic and physical practice trials was consistent and could not bias the child to prefer one version of the game. Having placed the pom pom behind a door the experimenter reminded the child, "That time you guessed before I threw the dice, didn't you?". The child was shown the die (which was manipulated to be consistent with the location of the pom pom if necessary), and the pom pom was pushed through the door. On epistemic practice trials children placed the mat after the pom pom was behind the door. Children were told, "This time you're going to guess when the pom pom is behind the right door". As on physical trials, if children guessed correctly by chance, the pom pom was pushed through the adjacent door.

After children had experienced guessing under both physical and epistemic uncertainty, on the subsequent test trial they chose when to guess, with the promise of a sticker if they guessed correctly. They were told, "You can guess before I've thrown the dice, or you can guess when the pom pom is behind its door. So which way do you want to play the game? Before I've thrown the dice, or when the pom pom is behind its door?". The experimenter manipulated the die so that children 'guessed' correctly and thus received a sticker, giving a pleasant end to the game for the child.

The Unspecified condition was the same except that we used the opaque box containing the diverse collection of objects. Children were told, "This box has lots of different things in it" and the experimenter referred to the object as "something". The experimenter emphasized that objects were not replaced in the opaque box and so something new was picked on each trial.

Results and discussion

Chi square tests confirmed that the order in which the conditions (specified or unspecified first) and the practice trials (epistemic or physical first) were presented had no effect on children's performance (lowest $p = .577$).

In the Specified condition, in which children knew the identity of the object, children preferred to guess when the pom pom was behind the door (epistemic uncertainty) rather than before the die was thrown (physical uncertainty), binomial test $p < .001$, Cohen's $g = .24$, see Table 1. In contrast in the Unspecified condition, in which children did not know the identity of the object, there was no preference, $p = .798$, $g = .02$.

There was a significant difference in children's preferences between conditions: McNemar test, $p = .019$, $\varphi = .10$. Children who preferred to guess under epistemic uncertainty in only one condition were more likely to do this in the Specified condition.

In summary, we replicated the preference to guess under epistemic rather than physical uncertainty reported by Robinson et al. (2009), but only when the object being hidden was known. When children did not know what object was being hidden, the preference disappeared. This supports the imagination account.

Experiment 2

In Experiment 1, children did not prefer to guess under epistemic rather than physical uncertainty when the object being hidden was unspecified. According to the imagination account this is because it was difficult for them to imagine 'something' in one of the possible locations: they were equally likely to choose to guess before or after the unspecified object was in place. This led us to make a further prediction.

Recall that Robinson et al. (2006) found that 59% of 4- to 6-year-olds in their sample placed only one mat to catch the falling object in the epistemic uncertainty trials. The imagination account predicts that if children are less likely to imagine the object in place then they should be less likely to behave as if there is only one possible outcome. Thus, under Unspecified conditions children should be able to mark multiple possibilities even under epistemic uncertainty. We tested this prediction in Experiment 2. We knew from Robinson et al. (2006) that 4- to 6-year-olds found it relatively easy to mark multiple possibilities under physical uncertainty (Specified conditions) and so the imagination account did not predict any change in performance under Unspecified conditions. Thus, in Experiment 2 we focused only on epistemic trials to test whether we could reduce the tendency for children to behave overconfidently under this type of uncertainty.

Method

Participants. Twenty nine children (16 girls, mean age 5;7, range 5;0 – 6;1) participated. They were recruited from and tested at a school serving a working and middle class population in the U.K..

Materials. We adapted the apparatus from Experiment 1 to have only two vertical sections colored green and orange. We used the pom poms, the collection of objects, the transparent box and the opaque box from Experiment 1 and in addition: blue blocks (approx. 1.5 cm cubed) and two gold mats (approx. 12 cm^2) cushioned with cotton wool.

Procedure. As in Experiment 1, children were tested individually. Each child played both the Specified and Unspecified conditions, with the order alternated between children. Children were shown the ‘Doors’ apparatus and told that the experimenter would take something from a box, put it behind one of the doors, and

they were to put out the mats to catch it. In the warm up trials the experimenter took a blue block from the table and placed it behind the green door. She told the child that she had put it behind the green door and directed her to put a mat under the green door. The experimenter then pushed the block through the door, where it landed on the mat. On a second warm up trial the experimenter did not tell the child where the block was. She placed the block behind the orange door and told the child to put out two mats to make sure the block was caught. The block was then pushed through the door and landed in one of the mats. The experimenter recapped that if the child knew which door the thing was going to fall from the right thing to do was to put out one cotton wool mat, and if she did not know which door the thing was going to fall from the right thing to do was to put out two cotton wool mats. The experimenter then removed the blocks from the table and told children that they were going to play the game for real.

Experimental Trials. In the Specified Condition, using the transparent container with the yellow pom poms , the experimenter placed a pom pom behind a door, without the child seeing which door. Children were asked to, "put out cotton wool to make sure you catch the pom pom" (as in Beck, Robinson, Carroll, & Apperly (2006) we used cotton wool so that we could refer to the mats without having to use a singular or plural instruction). When the mat or mats had been placed, the experimenter pushed the pom pom through a door, ensuring that if children had placed only one mat, they did not catch the pom pom. The experimenter then stated either "You caught it that time" when the child had placed two mats or "You didn't catch it that time" when they had placed only one. Mat(s) were removed from the doors and the game was repeated for two further Specified trials, making three Specified trials in total.

In the Unspecified Condition, as in Experiment 1, the game was played with the opaque box with objects of unknown identity. Three trials followed the procedure for the Specified Condition, except that the experimenter stated that she was putting 'something' behind the door, and asked children to put out cotton wool to make sure they caught 'the thing'.

Results and discussion.

Children were given a score of 1 on each trial on which they placed two mats (maximum 3). These data are shown in Table 2. Note that children were consistent in the number of mats they placed across all three trials in each condition. Chi square tests confirmed that the order in which the trials (specified or unspecified first) were presented had no effect on children's performance (lowest $p = .474$).

A Wilcoxon signed ranks test showed that scores were higher (i.e. children were more likely to place two mats) in the Unspecified Condition (16 out of 29 children always placed two mats) than in the Specified Condition (8 out of 29), $Z = -2.53$, $p = .011$, $CL = .66$. Nine children always placed two mats on the unspecified trials and never did so on the specified and only one showed the reverse pattern (Sign test $p = .021$). In line with the imagination account, children's success acknowledging possibilities was affected by whether they knew what the object was behind one of the doors.

The manipulation in Experiment 2 did not entirely ameliorate children's difficulty handling uncertainty. Children were more likely to place two mats (i.e. acknowledge uncertainty) in the Unspecified condition than in the Specified condition, and they were more likely to place two mats than just one. To some extent, 5-year-olds remained somewhat overconfident: 45% of children consistently placed only 1 mat under epistemic uncertainty even when the object was unspecified.

However, experiments 1 and 2 suggest that one reason children have difficulties responding appropriately to epistemic uncertainty is that they imagine the outcome and experience a false sense of confidence.

General Discussion

Our results offer an explanation for the surprising results reported by Robinson and colleagues (2006; 2009). Five- and six-year-olds, who typically behave as if they are thinking about only one possible outcome when uncertainty is epistemic, showed these behaviors less frequently when the object in the game was unspecified. They preferred to guess under epistemic rather than physical uncertainty only when they knew what the object in the hidden location was (Experiment 1) and they showed the expected tendency to acknowledge just one possibility only when they knew the object's identity (Experiment 2). Our explanation for this is that under Specified conditions they imagine one particular outcome. Under epistemic uncertainty they imagine the object in one of the possible locations. Under physical uncertainty children may be less inclined to imagine a single outcome as it has yet to happen. Thus, under Unspecified conditions, children are less likely to imagine the object in place and so are better able to acknowledge the multiple possible outcomes.

By what mechanism could imagining an object in place affect children's handling of uncertainty? It is unlikely to be due to the fact that it is easier for children to handle uncertainty in the fantasy domain as there were none of the vocal or behavioral cues that are typical when engaging children in pretense (Lillard & Witherington, 2004). More likely is that the ease with which children can imagine the object in place can lead to a metacognitive error, akin to fluency effects seen in adults (Alter & Oppenheimer, 2009). Adults feel more confident that they have experienced fictional events if these events have been imagined (Garry & Polaschek, 2000). These

effects result from increased ease of processing as imagined events become more familiar and source confusion (Sharman, Garry, & Hunt, 2005). It is plausible that children, whose source monitoring is still developing (see e.g. Robinson & Whitcombe, 2003), may be particularly susceptible to these effects and that this leads them to ignore alternative possibilities under epistemic uncertainty (when the outcome is easily imagined). If this is the case, then other factors that influence the ease with which children can imagine something, such as familiarity, may also affect performance.

Differentiation between physical and epistemic uncertainty has also been reported by researchers studying adults, although they do not use the same terms (e.g. Brun & Teigen, 1990; Chow & Sarin, 2002; Rothbart & Snyder, 1970). Adults predict they will prefer to guess about a chance event (e.g. the throw of a die) before it has happened. However, in reality they, like children, prefer to guess after the event (Robinson et al., 2009). They appear to be over-confident about their ability to guess under epistemic uncertainty compared to physical uncertainty. Perhaps the same process that leads children to behave more confidently under epistemic compared to physical uncertainty also influences adults. Adults might find it easier to imagine an outcome once it has happened rather than before and, having imagined this outcome, they may confuse this imagined outcome with a known outcome, or misinterpret the ease with which they imagined it as evidence for knowledge (a fluency effect, see e.g. Alter & Oppenheimer, 2009). If this is the case, we would also expect adults to be susceptible to the specified manipulation. Adults should rate themselves as more confident, or bet larger amounts, in tasks where they can easily imagine the outcome (e.g. specified versions of tasks) than those where they cannot (e.g. unspecified versions).

We limited our samples to 5- to 6-year-old children because we were confident they would show the preference for guessing under epistemic uncertainty and the difficulties in acknowledging possibilities arising from it and thus allow us to test our imagination account. We demonstrated that our manipulation affected their performance (removing the preference for guessing under uncertainty and facilitating their acknowledgement of multiple possibilities) and gained support for this account. Future research should pursue a developmental story detailing the role of imagination in responses to uncertainty at different ages. For example, when children first successfully mark multiple possibilities on physical uncertainty tasks (Beck et al. (2006) suggests this may be around 3 to 4 years of age) are they also able to mark multiple possibilities on epistemic uncertainty tasks if the object is difficult to imagine? When older (7- to 8-year-old) children pass the epistemic trials, are they still influenced by imaginability: if an outcome is made extremely easy for them to imagine would they slip back to treating it as if it could be known?

In conclusion, children's tendency to imagine outcomes leads to difficulty responding appropriately to epistemic uncertainty. While we have demonstrated this principle in one age group, research on epistemic and physical uncertainty should be expanded to give a truly developmental account of this domain. Uncertainty is one domain where excellent imaginative skills might do more harm than good.

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Table 1.

Children's preferences for physical and epistemic versions of the game in Experiment 1.

		Specified		
		Physical	Epistemic	Total
Unspecified	Physical	9	20	29
	Epistemic	7	25	32
	Total	16	45	

Table 2.

Number of times children placed two mats on Specified and Unspecified trials in Experiment 2.

		Specified				
		0	1	2	3	Total
	0	12	0	0	1	13
	1	0	0	0	0	0
Unspecified	2	0	0	0	0	0
	3	9	0	0	7	16
	Total	21	0	0	8	