British Journal of Psychology (2009), 100, 645–659
© 2009 The British Psychological Society

The British Psychological Society

www.bpsjournals.co.uk

Guessing imagined and live chance events: Adults behave like children with live events

E. J. Robinson[1]*, J. E. C. Pendle[1], M. G. Rowley[2], S. R. Beck[3] and K. L. T. McColgan[1]

[1]Department of Psychology, Warwick University, Coventry, UK
[2]Keele University, Keele, Staffordshire, UK
[3]University of Birmingham, Birmingham, UK

An established finding is that adults prefer to guess before rather than after a chance event has happened. This is interpreted in terms of aversion to guessing when relatively incompetent: After throwing, the fall *could* be known. Adults ($N = 71$, mean age 18;11, $N = 28$, mean age 48;0) showed this preference with imagined die-throwing as in the published studies. With live die-throwing, children ($N = 64$, aged 6 and 8 years; $N = 50$, aged 5 and 6 years) and 15-year-olds ($N = 93$, 46) showed the opposite preference, as did 17 adults. Seventeen-year-olds ($N = 82$) were more likely to prefer to guess after throwing with live rather than imagined die-throwing. Reliance on imagined situations in the literature on decision-making under uncertainty ignores the possibility that adults imagine inaccurately how they would really feel: After a real die has been thrown, adults, like children, may feel there is less ambiguity about the outcome.

When asked to bet on a chance outcome with a known probability of success, such as the fall of a die, adults prefer to guess before the die has been thrown rather than after. They also bet larger amounts before than after, and rate themselves more certain about the outcome before than after (Brun & Teigen, 1990; Chow & Sarin, 2002; Rothbart & Snyder, 1970). Such betting preferences appear to be irrational, since the known objective probability of success is exactly the same whether the die has been thrown or not. Similar preferences have been reported in a variety of other uncertain situations such as the state of the stock market, or the outcome of a football match. The assumption is that betting provides a proxy measure of confidence.

The findings have been interpreted within Heath and Tversky's (1991) competence hypothesis: The suggestion is that adults prefer to bet (feel more confident) when they feel competent rather than incompetent. Feelings of incompetence arise when there is something they could in principle know but do not, or when somebody else already

* *Correspondence should be addressed to Professor E. J. Robinson, Department of Psychology, Warwick University, CV4 7AL Coventry, UK (e-mail: e.j.robinson@warwick.ac.uk).*

DOI:10.1348/000712608X386810

knows something about which they themselves remain in ignorance. Heath and Tversky's (1991) evidence to support the competence account relate to betting under conditions when adults had some knowledge, for example about football or politics, rather than for entirely chance events like the throw of dice, but they explicitly generalize the account to chance events such as the predicting the throw of a die. Their argument is that when adults are incompetent, betting success tends to be attributed to chance and failure to ignorance, so they gain no credit for success but blame for failure. In contrast, when adults are more competent, failure can be attributed to chance and success to knowledge, so they gain credit for success but no blame for failure. Hence betting under feelings of relative competence is more attractive than under feelings of relative ignorance (for further relevant evidence on fear of negative evaluation, see Trautmann, Vieider, & Wakker, 2008).

This interpretation of the findings implies that adults spontaneously consider their own state of ignorance about an uncertain outcome in relation to what they *could* know: They could know what another person already knows, or they could know what has happened but remains hidden. When the uncertain event is as yet undetermined, at the current time there *is* no more they could know. Other than a shift in temporal perspective, there is no more knowledgeable position they could be in.

If adults' guessing preferences arise from feelings of relative competence under undetermined conditions, when and why do concerns about one's relative knowledge or competence arise developmentally? When and why do children spontaneously consider their own state of ignorance in relation to what they could know?

As will become clear below, during the course of attempting to answer this developmental question, a further, unexpected, question emerged, concerning adults' ability to imagine accurately how they will feel when making a decision under uncertainty. Our argument will be that although adults commonly *imagine* that they will prefer to predict an event whose outcome is yet to be determined, in real life decision-making about chance events, both children and adults prefer to predict an unknown event that has already happened. That is, we shall argue that adults commonly make a simulation error when they imagine these circumstances. When people are faced with a real event that has already happened but remains unknown, we shall argue, they experience feelings of relative confidence, not relative incompetence, that bear similarity to children's over-estimation of their knowledge of the unknown. The known existence of an unknown reality appears to influence the decision-making of both children and adults.

This argument is developed by the following route. First, since in the adult literature most studies ask participants to place a bet, and this would be unacceptable in research involving children, we began by checking that when adults are asked simply to guess the fall of a die, they prefer to do so before the die has been thrown rather than after (Experiment 1). As in virtually all the published studies involving betting, our adult participants made judgments about imagined situations in a paper-and-pencil task (the only live event we have found is Rothbart & Snyder, 1970). We went on to test the guessing preferences of children aged 6 and 8 years (Experiment 2), and aged 5 and 6 years (Experiment 5) using live tasks because paper-and-pencil tasks were unsuitable for children that age. These ages were selected on the basis of predictions from the developmental literature, as shown in the introduction to Experiment 2. In the light of the unexpected absence of age-related changes in children's guessing preferences, in Experiments 3 and 4 we examined the guessing preferences of adults using live tasks to check (i) whether or not the adult preference found in imagined situations were also

found in live ones, and (ii) whether or not adults' preferences in live situations differed from those of children.

EXPERIMENT 1

The aim of this experiment was to develop a guessing task that was similar to the chance betting tasks used in the published literature involving adults (Brun & Teigen, 1990; Chow & Sarin, 2002; Rothbart & Snyder, 1970), but that was also suitable for children, and to establish using that game whether adults preferred to guess before rather than after the outcome had been determined. Our expectation was that the published finding would be replicated, with adults preferring to guess before the die was thrown rather than after.

Method

Participants

Seventy one undergraduate students comprised sample 1 (24 male, 47 female). They were in their first year at university and were aged 17;2 to 22;1, $M = 18;11$. Sample 2 comprised of 28 parents or guardians (9 male, 19 female) of potential undergraduates who visited a university Open Day with their children. Their ages ranged from 35 to 57, mean 48;0.

Design and materials

Participants completed a questionnaire printed on a single sheet of A4 paper. The order of choices for the dependent measures on the questionnaire was counterbalanced between groups of participants.

Procedure

Participants in sample 1 were tested in their lecture class, and participants in sample 2 were tested individually. Both followed the same procedure, completing a brief questionnaire based closely on the studies cited above, but avoiding mention of betting. The opening text of this questionnaire asked participants to imagine they were given a standard die, would shake it and let it fall out of sight so that nobody could see what number had come up. This brief text was accompanied by illustrative photographs. Participants were then asked to imagine they were to guess the fall of the die, and would win a cash prize if they were correct. Participants then filled in the questionnaire to indicate whether they would prefer to guess the fall of the die before they had thrown it, or after they had thrown it without anybody seeing.

Results and discussion

In sample 1, 49 participants preferred to guess before the die was thrown, and 22 preferred to guess after (Binomial $p = .002$). In sample 2, 24 preferred to guess before, and 4 preferred to guess after ($p < .001$).There were no gender differences. In line with the published literature, adults preferred to guess when the outcome was as yet undetermined, rather than when it was determined but unknown. We were therefore in a position to examine age-related differences in guessing preferences.

EXPERIMENT 2

The results of Experiment 1 are in line with the published literature, and with Heath and Tversky's (1991) competence hypothesis, according to which adults consider their own state of ignorance about an uncertain outcome in relation to what they could know, and prefer not to guess when they are in a position of relative ignorance. The developmental literature provides a basis for making tentative predictions about children's concerns about their own relative competence. Children begin to engage in counterfactual reasoning from about the age of 4 years (e.g. Beck, Robinson, Carroll, & Apperly, 2006; German & Nichols, 2003; Guajardo & Turley-Ames, 2004; Harris, German, & Mills, 1996; Robinson & Beck, 2000). However the ability to engage in counterfactual reasoning might not be sufficient for children to infer that they know less than they could, since the reported adult aversion to guessing when in such a state of relative ignorance, involves a comparative, evaluative component. We can draw an analogy with regret, for which there are developmental data. Feelings of regret arise when one considers what actually happened in relation to a better outcome that could have happened. Children show evidence of understanding regret in an adult-like manner by around age 7 years (Guttentag & Ferrell, 2004). Children heard stories in which two characters experienced the same negative outcome, for example cycling into a fallen tree. One character had taken his normal route while the other made an unusual deviation from the normal route. The adult-like pattern would be to judge that the latter person would experience regret at having deviated from his normal route; the negative outcome could have been avoided. Seven-year-olds judged in this way, while 5-year-olds did not. Although younger children can imagine the counterfactual situation and report accurately how a person in the alternative situation would feel, they appear not to evaluate the protagonist's own position in relation to what it could have been (Amsel & Smalley, 2000).

Insofar as we can generalize to children's handling of their own relative ignorance, the prediction from the competence account is that by around 7 years children might begin to show adult-like preference for guessing before throwing (when they are not in a position of relative ignorance) rather than after (when they could in principle know the outcome). Younger children, unable to make the comparison between what they *do* know and what they *could* know, might show no preference for guessing before or after throwing. In that respect, children younger than 7 years might be more rational in their guessing behaviour than older children and adults.

On the other hand, children younger than 7 years might be subject to a different bias: They might be more likely to assume they know the outcome of an event that has already happened, than one that is yet to happen. Young children tend to overestimate their knowledge under conditions of uncertainty, to a much greater extent than older children and adults (e.g. Beal, 1988; Braine & Rumain, 1983; Fay & Klahr, 1996; Klahr & Chen, 2003; Taylor, 1988). In this research children make judgments about an event that has already happened, for example a model has already been constructed out of one of a set of pieces, or a toy has been hidden in one of a set of possible locations. Children aged around 4 to 6 years frequently behave as if they know more about the unknown event than they really do.

There is some evidence that children are more inclined to overestimate their knowledge when there *is* something of which they are ignorant, than when as yet the event has not yet happened. Robinson, Rowley, Beck, Carroll, and Apperly (2006) gave children aged between 4 and 6 years, tasks in which they had to acknowledge the two possible outcomes of an event that had either already happened, or was as yet undetermined. In one game, a block could fall from one of two doors, and to be sure of

catching it children had to place trays under both. On some trials, a block was already hidden behind one of the doors before children were invited to put out catching trays. In another condition, children put out trays when no block was yet in place and it had not yet been determined which door it would fall from (this was determined by the colour of the block that was picked randomly from a bag containing blocks of different colours). Children were more likely correctly to cover both possibilities in the latter condition, when the event was as yet undetermined, than the former. In the former condition, when children knew a block was already hidden behind one of the doors, children tended to put out only a single tray, risking missing the block if it fell from the unprotected door. Similar findings were reported for a narrative task in which one pet could be in one of two boxes, both of which needed to be supplied with food to ensure the pet did not starve. Six-year-olds were more likely correctly to cover both possibilities when the pet was not yet in either box, and more likely to put food in only one box when the pet was already in one of the boxes but its location was unknown.

Insofar as children made a single interpretation when the unknown event had already happened, they behaved as if they knew what the outcome was. In contrast, insofar as they acknowledged both possibilities when the event was as yet undetermined, children behaved as if they did not know the outcome. As Robinson *et al.* (2006) point out, children seemed to show the opposite pattern to that of adults: Children seemed more confident of knowing the outcome when an unknown event has already happened, and more inclined to hedge their bets, acknowledging both possibilities, in undetermined conditions.

Assuming an age-related decline in over-estimation of knowledge, the prediction is that younger children will prefer to guess after the die has been thrown rather than before, and that this preference will decline with age. As children's over-estimation of their knowledge of the hidden reality declines, so their focus on what they *could* know, along with concern about relative competence, might replace it.

To test this prediction, in Experiment 2 our child participants, aged 6 and 8 years, played individually with the experimenter a live version of the task imagined by the adults in Experiment 1. Our expectation was that 6-year-olds would be likely to think they knew how the die had fallen, and so would prefer to guess after throwing. In contrast 8-year-olds children would be more likely to be aware that they *could* know how the die had fallen, yet did not, and so be averse to being in such a position of relative ignorance. They would therefore begin to show the adult-like pattern of preferring to guess before throwing.

Method

Participants

Thirty two younger children (15 female, 17 male) attending a Year 1 class (age range = 5;5 to 6;5, $M = 6$ years) and thirty two older children (17 female, 15 male) attending a Year 3 class (age range = 7;6 to 8;6, $M = 8$ years) participated in this experiment. All attended a primary school in Warwickshire, UK.

Design

Each child played two practice games, one *determined* (throw then guess) and one *undetermined* (guess then throw), followed by a choice between the two for the third game. The choice made was the dependent variable. The order in which the practice

games were played and the order of presentation of the forced choice alternatives in the choice question, were counterbalanced.

Materials

Five differently coloured cups and dice of matching colour were used, enabling children to choose which cup and die to use for each of the three games. Six picture cards representing the six different faces of a die were also used. Stickers were used as an incentive for guessing the correct number in the third game.

Procedure

The experimenter began by demonstrating how to throw a die in the game, by shaking it in its matching cup, turning the cup upside down on the table, and lifting the cup off only when told to by the experimenter. Children then practiced shaking a die in this manner. The two practice games followed. Children were asked which cup they would like to play with. For the *determined* practice, children were told, 'This time you are going to shake first, and then guess what number it is.' The child shook the die, left it hidden beneath the cup. The experimenter placed the six picture cards representing the six faces of the die on the table and asked the child to guess the outcome: 'So what number do you think it is?' Children were given the card that corresponded to their guess, and then were allowed to see if they were right.

The *undetermined* practice was similar except that children were told they were going to guess what the number on the die was going to be, before shaking the die. Children guessed, were given the corresponding number card, then shook the die and checked whether they were right.

The *choice* game followed the two practice games. Children were told that they could choose which of the two games to play, and would win a lovely sticker if they guessed the correct number. Children were reminded of the two games, with the experimenter acting out the temporal sequence of events using the cup that the child had initially played with for each practice game. Finally, children were asked the choice question: 'You can guess first and then shake (with appropriate miming by experimenter), or you can shake first and then guess, while the dice is underneath the cup (with appropriate miming by experimenter). So what do you want to do? Guess first then shake, or shake first then guess?' Whichever version the child chose was then played. Children were given a sticker whether or not they guessed correctly.

Results and discussion

Children's preference might have been influenced by whether they happened to guess correctly on one or other of the practice games, so we excluded children whose guesses were correct on one but not both practice games. Amongst remaining 6-year-olds ($N = 20$), 19 chose to play the determined version of the game and 1 chose the undetermined version (Binomial, $p < .001$); amongst remaining 8-year-olds ($N = 24$), 17 chose to play the determined version of the game and 7 chose the undetermined version (Binomial, $p = .064$). The 8-year-olds were less likely than the 6-year-olds to prefer the determined game: Fisher exact $p = .05$. The preference for the determined game (throw first) remained when all children were included (6-year-olds, $p = .001$; 8-year-olds, $p = .05$), showing that exclusions did not create a different pattern of preferences.

Hence the 6-year-olds responded as predicted. Although the preference for the determined game was only marginally significant for the subsample of 8-year-olds, the data clearly provide no grounds for arguing that a preference for the undetermined game has begun to appear. Assuming at some point in development young people begin to show adult-like preferences for guessing before throwing, and in the absence of any theoretical rationale for predicting a particular point beyond the age of 8 years when this might happen, further investigation of age-related differences would be based merely on trial and error. Working down from the 18-year-old undergraduates we tested in Experiment 1, in Experiments 3 and 4 we tested secondary school students aged 15, 16 and 17 years.

At the same time, we checked on the possible influence of the confounding variable of imagined versus live die-throwing. In most of the published research on adults' decision-making under uncertainty, participants are asked to imagine betting on uncertain events. One exception is Rothbart and Snyder (1970), who allowed their participants to throw real die, and their results were consistent with the other studies (but see our comment in the discussion of Experiment 4). Despite the preponderance of studies using imagined tasks, the theories explaining the results are intended to apply to real-life decision-making (Ellsberg, 1961; Fox & Tversky, 1995; Heath & Tversky, 1991), for example in business settings (Fox & Tversky, 1995). Perhaps we, along with researchers into adults' betting preferences, were wrong to assume that live and imagined events would be treated in the same way. An indication that this could be the case comes from Hertwig and Ortmann's (2001) analysis of the decision-making literature more broadly. These authors argue robustly that participants behave differently in important ways when their decisions have real financial consequences. We return to their argument in the final discussion.

EXPERIMENT 3

We compared live and imagined events within a single sample of 17-year-olds. As indicated above, we had no strong grounds for predicting a difference, but good grounds for checking the validity of the assumption of no difference.

Method

Participants

There were 82 participants (28 male and 54 female), all of whom were students in a selective secondary school in Birmingham, UK. Their ages ranged from 16;1 to 18.11, mean 17;5.

Design and materials

Participants were allocated to one of two conditions: Live or imagined. We used two differently coloured die, two white cups, and a box with a lid for the live condition. Participants wrote their responses in a small booklet, in which the order of options was counterbalanced between participants.

Procedure

Participants were tested in their classes, ranging in size from 16 to 21, but were physically separated to ensure they made individual judgments. Three classes entered the *live* condition, and two entered the *imagined* condition. This unequal distribution

took into account the fact that some participants in the live condition would be eliminated for guessing correctly in the demonstration phase of the task.

Participants in the *live* condition followed a procedure very similar to that used with the children in Experiment 2, except that they watched the experimenter play the games, rather than throwing the dice themselves (see below for a check on the importance of this difference). Participants watched as the experimenter demonstrated the determined and undetermined games, with one class having the undetermined game demonstrated first, and two classes having the determined game demonstrated first. This imbalance took into account the high number of participants who guessed correctly in the first class that had the determined game demonstrated first. As each game was demonstrated, participants wrote down their guesses and found out whether they were correct. They then indicated their preferred way of playing for the third time, wrote down a reason, and then made their third guess and observed as the experimenter played both games, and checked whether they were right. One of the two classes in the live condition with the undetermined game first, played the games with the die inside a box that was placed casually out of sight once the die had been thrown, rather than with a cup that was placed in full view on a table. This matched the imagined situation. This variable of visible versus hidden die container had no hint of an effect on guessing preferences within the live condition, and will not be mentioned again.

Participants in the *imagined* condition underwent a similar procedure except that in the first part of the game there were no live demonstrations of the determined and undetermined versions. Instead, participants were asked to imagine they had a die inside a box and could guess its fall either before shaking it or after. This part of the procedure was closely based on Brun and Teigen (1990). Participants then indicated their preference, wrote down their reason, and the experimenter played live versions of the game as in the live condition.

Results and discussion

As in Experiment 2, in case successful guessing in the demonstration games influenced participants' preferences, we excluded participants who guessed correctly in only one of the demonstration games (live condition only), leaving 58 participants. Of the 28 participants in the live condition, 19 preferred to guess under determined conditions, and 9 preferred to guess under undetermined (binomial $p = .087$). (Without exclusions, $N = 52$, 35 preferred determined and 17 undetermined, $p = .02$. The exclusions do not create a different pattern of preferences). Of the 30 participants in the imagined condition, 12 preferred to guess under determined conditions and 18 under undetermined (ns). The difference in preference between live and imagined conditions was significant: χ^2 uncorrected ($N = 58$) $= 4.52$, $p = .034$.

Unexpectedly, guessing preferences seem to be different for live and imagined die-throwing. When witnessing live die-throwing, our young adult participants in Experiment 3 tended towards the same preference as 6- and 8-year-old children in Experiment 2: To guess after the die had been thrown. In contrast, those who only imagined throwing a die showed no hint of such a preference, although we did not find the significant preference for guessing before throwing that appeared in Experiment 1. We discuss this further in the final discussion.

One reason was given by 23 participants who preferred the determined game (14 live and 9 imagined): The outcome was already decided, or was more certain. For example:

'Because the number is already there just not able to be seen. If you are guessing the outcome of something that hasn't taken place yet, the probability of getting it right appears to be lower'; 'Because, although absurd, I feel that there may be more chance of a correct answer, even though there is no mathematical evidence to back this up. I feel more confident with this game'; 'You feel as though you have more chance of predicting the right number because it has already been determined.' 'Because it feels as if there is more of a definite answer even though both methods rely on luck and guesswork. It would seem more impossible to guess a number then shake'; 'More definite, pre-determined'; 'The outcome has already happened so it seems less of a random guess, although the probability of getting it correct is the same.'

This reason was also given by four participants who preferred the undetermined game, for example, 'In the guess then shake you are making a totally random decision. In the shake first, the die is already there, you just can't see it.' Note that participants were asked to give their preference, not to indicate which game they thought they were more likely to guess correctly. Possibly some people preferred the excitement of what seemed the less predictable game. 'You have less chance of knowing the number'; 'Guessing prior to shaking evokes a greater sense of anticipation as to the accuracy of the prediction in relation to the outcome.' Overall, reasons for preferring the undetermined game were much more varied and no one reason was given more than four times.

Since the surprising finding in Experiment 3 was the preference for guessing after throwing in the live condition, and there is no reason to doubt the well established preference for guessing before throwing in imagined conditions, in Experiment 4 we checked on the replicability of our results with live die-throwing, using two larger samples.

EXPERIMENT 4

Using Experiment 3's live condition only, we tested two larger samples of young people.

Method

Participants

The first sample consisted of 93 young people (26 male and 67 female) aged 15;01 to 17;02, mean 15;11. The second sample consisted of 46 participants (20 male and 26 female) aged 15;0 to 16;0, mean 15;3. All participants attended secondary schools in Staffordshire, UK.

Design and materials

All participants saw the live version of the task. The order of the demonstrations was counterbalanced, as was the order in which the options were offered. Materials were a red and a green cup, with matching dice. Participants were given sheets on which to fill in their age and gender, and to write down their guesses for each of the games, with reasons.

Procedure

Participants were tested in groups of around 20 to 25. The experimenter showed participants the red and green cups and dice, and explained that they were going to guess what number would come up on a die. He went on to demonstrate one game, determined or undetermined, with the red cup and die, and the other game with the green cup and die. The order of demonstrations and the colour of cup were

counterbalanced independently between groups. As in the live condition of Experiment 3, for each demonstration game, participants wrote down their guess either before or after the experimenter threw the die, and then found out whether or not it was correct. Participants then chose which of the two games they preferred to play for their final game, and why. They made their guess, and the experimenter completed the session by playing both games and letting participants know whether or not they were correct.

Results and discussion

As before, we excluded participants who guessed correctly on one of their two demonstration games. In the first sample, 67 participants remained, 48 of whom preferred determined for their third game (binomial $p = .001$). In the second sample, 37 participants remained, 31 of whom preferred determined for their third game (binomial $p < .001$). Reasons given for preferences were very similar to those given in Experiment 3. Again, a common reason for preferring the determined game was related to the fact that the outcome was decided at the time of guessing ($N = 47$ in both samples combined). Those who preferred the undetermined game most frequently referred to colour preference for the red or the green game ($N = 9$), or to a random choice ($N = 4$) with no other reason appearing more than three times.

Consistent with the tendency in Experiment 3, when witnessing live die-throwing, participants preferred to guess after rather than before the die had been thrown. Perhaps the preference for guessing under undetermined conditions arises with both live and imagined die-throwing some time after the ages of 15 years (Experiment 4), and after 17 years (Experiment 3), but is in place by 18 years (Experiment 1). Alternatively, perhaps it is relevant whether the participant or the experimenter throws the die, although the pattern of results makes this unlikely: In Experiment 1, adults imagined throwing the die themselves, as in the imagined condition of Experiment 3 (preference for undetermined). In Experiment 4, and in the live condition of Experiment 3, participants watched the experimenter throw the die (preference for determined). In Experiment 2, children threw the die themselves (preference for determined). Nevertheless, in Experiment 5 we checked on whether children's preference for guessing under determined rather than undetermined conditions remained when the experimenter threw the die.

EXPERIMENT 5

We compared children's preference for guessing before or after the die had been thrown under two conditions: The first was as in Experiment 2, with the children throwing the dice themselves, and in the other condition, children watched as the experimenter threw the die, as with the adult participants in Experiment 3's live condition and in Experiment 4. We included children slightly younger than those in Experiment 2: we were no longer looking for a shift in guessing preference between 6 and 8 years, so we took the opportunity to find out whether the preference to guess after throwing appeared in children younger than 6 years.

Method

Participants

Twenty five younger children (14 female, 11 male) attending a reception class (age range 4;8 to 5;8, $M = 5;2$ years) and 26 older children (13 female, 13 male) attending a year 1

class (age range = 5;9 to 6;8, $M = 6;2$ years) took part. All attended a primary school in Warwickshire, UK.

Design and procedure

Each child played under both conditions, Child Shakes and Experimenter Shakes, with the order of conditions counterbalanced. In each condition, children played two demonstration games, one undetermined (guess first) and one determined (shake first), and then were asked to choose their preferred game for the third throw. The choice made was the dependent variable. The order in which the demonstration games were played and the order of presentation of the forced choice alternatives in the choice question were counterbalanced.

The materials and procedure were very similar to those of Experiment 2, but with either the child or the experimenter shaking the dice depending on condition. A further difference was that in the demonstration games children did not see if their guess had been right. Instead the cup remained on top of the die, and the card that they had selected was placed on top of it. Children were told that, 'We're going to leave the cup on top of the dice and wait until the end of the game to see if you're right'. This meant we avoided excluding children who got one of their demonstration trials correct.

Results and discussion

There were no age differences in children's performance in either condition, so the two age groups were collapsed for subsequent analysis. In the Child Shakes condition, 41 children out of 50 chose to play the determined version, throw then guess (Binomial, $p < .001$). In the Experimenter Shakes condition, 39 out of 50 chose to play the determined version (Binomial, $p < .01$). There was no significant effect of the order in which children received these versions, and there was no significant effect of the order in which the games were presented in the forced choice question.

Hence the results confirm children's preference for guessing under determined conditions when they throw the die themselves, and show that this preference is maintained when the experimenter throws, as with the adult participants in Experiments 3 and 4.

Further data also show that adults prefer to guess under determined conditions when they throw the die themselves: We examined a sample of 17 adults aged 20 years and over, who were attending short courses at a further education college. These people were tested individually using the same procedure as with children in Experiment 2, throwing the dice themselves, and with a prize of chocolate if they guessed correctly in their third game. Excluding 5 participants who guessed correctly in one of their demonstration games left 12 participants, 11 of whom preferred to shake first the die, and one preferred to guess first (binomial $p = .006$). With live rather than imagined die-throwing, adults' preference for guessing after throwing is not confined to circumstances when the throwing is merely observed, and neither is it confined to people younger than 18 years, the other possibility raised above.

There seems, then, to be something about guessing the outcome of a live event that engenders a feeling of relative confidence when the event has already happened. We discuss this further in the final discussion. First, however, we consider the contradiction between our results and Rothbart and Snyder's (1970) finding, using live die-throwing, that participants were more confident when they guessed before

rather than after throwing. Unlike our studies, Rothbart and Snyder's participants experienced either the determined or the undetermined game once only. They therefore had no opportunity to make a comparison between the different orders of events. In addition, at the time participants in the undetermined condition made their bets at the start of the game, they were in effect basing their judgments on an imagined event. In contrast, in our studies, participants experienced guessing before and after throwing and only then expressed their preferred way of playing.

FINAL DISCUSSION AND CONCLUSIONS

In attempting to answer our initial research question, 'When and why do concerns about one's relative knowledge or competence arise developmentally?' we uncovered a further, unexpected question, 'Under what conditions do adults show concern about their relative knowledge?' Although the results of Experiment 1 confirmed that adults prefer to guess about a chance event before it has happened rather than after, results of Experiments 3 and 4 suggested that this preference was confined to circumstances when adults imagined the events, and did not appear when they experienced live events.

Since we could examine young children's guessing preferences only with live events, it was not surprising that the results failed to show the predicted age-related change guessing preference. Our prediction from the developmental literature on regret was that an adult-like preference to guess before throwing the die could be in place amongst 8-year-olds, but not in 6-year-olds. From the developmental literature on children's handling of limited information, we predicted that 6-year-olds, instead of treating the hidden die already thrown as something they *could* know, might treat it as if they *do* know how it had fallen. Hence instead of being averse to guessing after the die was thrown, we predicted they might prefer that order of events.

As predicted, 6-year-old children preferred to guess an event that had already happened, as did 5-year-olds (in Experiment 5), whether they threw the die themselves or observed the experimenter throw. Contrary to prediction, 8-year-olds also preferred to throw then guess, although the preference was only marginally significant, as did 15-year-olds and 17-year-olds who observed live events, and adults who threw the dice for themselves (like the child participants). Across the age range, when participants made judgments about live events, there was no evidence of concern over their relative incompetence; they did not avoid guessing about something they *could* know but did not. The minor differences in procedures across the experiments gives confidence that the effect is not narrowly confined to tasks with some specific feature. Overall, with live events there was no support for Heath and Tversky's (1991) competence account.

As mentioned in the introduction, the evidence Heath and Tversky amassed to support the competence account was based not on guessing chance events, but rather involved (imagined) situations about which participants knew something, such as the outcome of football matches or politics. It remains a possibility that for this kind of uncertain event, live decision-making preferences, like imagined ones, are in line with the competence account.

On the other hand, there is other evidence of important differences between how people imagine they will feel in certain situations and how they actually feel, so it perhaps is not surprising if people simulate inaccurately how they will feel when predicting chance events. Studies documented by Gilbert (2007) show how people overestimate the impact of future positive or negative events, compared with the impact

they really have. Gilbert explains this partly in terms of inability to ignore our current feelings, knowledge or perspective when simulating a different future, which cannot explain our results. More relevant is Gilbert's (2007) suggestion that we set up incorrect contexts when simulating: 'When we imagine future circumstances, we fill in details that won't really come to pass and leave out details that will.' (p. 238). In the die-throwing task, perhaps when imagining the games, people are more likely than they are in reality, to set up a comparison between what they do know and what they could know.

Further evidence of inaccurate simulation comes from Hertwig and Ortmann (2001), who show that over a range of circumstances, decision-making behavior can be different, and also less variable, when participants' decisions have real financial consequences, rather than when they merely imagine the consequences, when they become familiar with the decision-making situation through extended practice rather than having a single trial, and when they enact a 'script' that makes as clear as possible what the relevant conditions are. Despite giving credence to the possibility that people's decision-making is different under live and imagined conditions, Hertwig and Ortmann's (2001) interpretation does not accommodate our findings. They assume that participants' scarce 'cognitive effort' is more likely to be utilized when there are real financial incentives (p. 391). In our experiments, adults in the live conditions in Experiments 3 and 4 were offered no incentives, financial or otherwise, so some other factor must explain differences we found between guessing under live and imagined conditions.

Given that our results with live die-throwing are not in accordance with Heath and Tversky's competence account, is there an alternative explanation already in the literature? One possibility is the dual-process theory developed to account for a different bias in adult reasoning, the ratio-bias phenomenon (Kirkpatrick & Epstein, 1992; Pacini & Epstein, 1999). In the ratio-bias phenomenon, participants show an irrational preference for choosing from a large array rather than a small one, when the two arrays have exactly the same likelihood of success. For example, participants prefer to choose from a set of 10 in 100, rather than from 1 in 10. Just as our adult participants realized that the chance of guessing correctly was exactly the same whether they guessed before or after throwing the die, participants in the ratio-bias experiments understand that their chance of success is the same whether they pick from the large or the small array. Yet they experience a preference for one condition over the other. Kirkpatrick and Epstein (1992) suggest that this irrational preference arises from a heuristic processing system that is preconscious and processes information automatically. In contrast, the analytic processing system is conscious, and relies on understanding of conventional logic. One problem with applying this dual process account to our results is that we identified two different irrational biases: With simulated events adults showed an irrational bias for guessing first, while with live events, they showed the equally irrational bias for throwing first. It seems unlikely that a single heuristic will be able to explain not just why participants held irrational biases despite knowing that they were irrational, but why their irrational biases differed in direction according to live versus simulated guessing conditions.

Perhaps it is worth considering at this point exactly how strong participants' biases really were. Our adult participants often commented that it really did not matter whether they guessed before or after throwing, and indeed we assumed at the outset that both they and the children did realize that. Had participants been given the option of responding 'no preference' when asked how they would like to play the game, many

of them might have chosen that option, if only to demonstrate that they understood the logic of the situation. One possibility is that children would maintain a preference for determined conditions even when given the option of stating 'no preference': They might feel more confident than adults that they do know how the die has fallen in the determined version of the game. However strongly or weakly participants of different ages held their preferences for guessing under determined or undetermined conditions, importantly there was consistency in the direction of preference across individuals. Even if each person had only a weak preference for guessing under determined conditions with live die throwing, and under undetermined conditions with simulated die throwing, the finding that these preferences are strongly shared across individuals requires explanation.

We suggest that Ellsberg's (1961) ambiguity account might provide such an explanation for the bias under live conditions. The reasons given by participants in Experiments 3 and 4 for preferring to guess after the die has been thrown suggest that what they find aversive is the uncertainty of the undetermined event. Although Ellsberg aimed to account for the finding that people prefer to bet on known rather than unknown probabilities (whereas in our die-throwing studies the probabilities were always known), Ellsberg argued more generally that people's willingness to act under uncertainty depends not only on the perceived probability of the event, but also on its vagueness or ambiguity (Ellsberg, 1961; Fox & Tversky, 1995). Our adult participants in the live conditions, along with a minority in the imagined conditions, seemed to consider that once the die has been thrown, *what* is to be guessed is fixed. In contrast, before it has been thrown, no outcome has yet been fixed in reality, so there is as yet nothing *to* guess. Our participants seemed to perceive this latter situation to be more ambiguous.

If this is an accurate characterisation of adults' thinking about live chance events, we need to explore further the developmental question hinted at above: To what extent do adults' and children's preferences for guessing determined rather than undetermined events arise from the same underlying realism, the impact of the known unknown?

Acknowledgements

The research was supported by a grant from the Economic and Social Research Council, UK (RES-062-23-0335).

References

Amsel, E., & Smalley, D. J. (2000). Beyond really and truly: Children's counterfactual thinking about pretend and possible worlds. In P. Mitchell & K. J. Riggs (Eds.), *Children's reasoning and the mind* (pp. 121–147). Hove, UK: Psychology Press.

Beal, C. R. (1988). Children's knowledge about representations of intended meaning. In J. W. Astington, P. L. Harris, & D. R. Olson (Eds.), *Developing theories of mind* (pp. 315–325). Cambridge: Cambridge University press.

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

Braine, M. D. S., & Rumain, B. (1983). Logical reasoning. In J. H. Flavell & E. M. Markman (Eds.), *Cognitive development* (4th ed., Vol. III, pp. 266–340). New York: John Wiley and Sons.

Brun, W., & Teigen, K. H. (1990). Prediction and postdiction preferences in guessing. *Journal of Behavioral Decision Making*, *3*, 17–28.

Chow, C. C., & Sarin, R. K. (2002). Known, unknown and unknowable uncertainties. *Theory and Decision*, *52*, 127–138.

Ellsberg, D. (1961). Risk, ambiguity and the savage axioms. *Quarterly Journal of Economics*, *75*, 643–669.

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

Fox, C. R., & Tversky, A. (1995). Ambiguity aversion and comparative ignorance. *Quarterly Journal of Economics*, *110*, 585–603.

German, T. P., & Nichols, S. (2003). Children's counterfactual inferences about long and short causal chains. *Developmental Science*, *6*, 514–523.

Gilbert, D. (2007). *Stumbling on happiness*. London: Harper.

Guajardo, N. R., & Turley-Ames, K. J. (2004). Preschoolers' generation of different types of counterfactual statements and theory of mind understanding. *Cognitive Development*, *19*, 53–80.

Guttentag, R., & Ferrell, J. (2004). Reality compared with its alternatives: Age differences in judgments of regret and relief. *Developmental Psychology*, *40*, 764–775.

Harris, P. L., German, T., & Mills, P. (1996). Children's use of counterfactual thinking in causal reasoning. *Cognition*, *61*, 233–259.

Heath, C., & Tversky, A. (1991). Preference and belief: Ambiguity and competence in choice under uncertainty. *Journal of Risk and Uncertainty*, *4*, 5–28.

Hertwig, R., & Ortmann, A. (2001). Experimental practices in economics: A methodological challenge for psychologists? *Behavioral and Brain Sciences*, *24*, 383–451.

Kirkpatrick, L. A., & Epstein, S. (1992). Cognitive-experiential self-theory and subjective probability: Further evidence for two conceptual systems. *Journal of Personality and Social Pychology*, *63*, 534–544.

Klahr, D., & Chen, Z. (2003). Overcoming the positive capture strategy in young children: Learning about indeterminacy. *Child Development*, *74*, 1275–1296.

Pacini, R., & Epstein, S. (1999). The interaction of three facets of concrete thinking in a game of chance. *Thinking and Reasoning*, *5*, 303–325.

Robinson, E. J., & Beck, S. R. (2000). What is difficult about counterfactual reasoning? In P. Mitchell & K. J. Riggs (Eds.), *Children's reasoning and the mind* (pp. 101–119). Hove, UK: Psychology Press.

Robinson, E. J., Rowley, M., Beck, S., Carroll, D., & Apperly, I. (2006). Children's sensitivity to their own relative ignorance: Handling of possibilities under epistemic and physical uncertainty. *Child Development*, *77*(6), 1642–1655.

Rothbart, M., & Snyder, M. (1970). Confidence in the prediction and postdiction of an uncertain outcome. *Canadian Journal of Behavioral Science*, *2*, 38–43.

Taylor, M. (1988). Conceptual perspective taking: Children's ability to distinguish what they know from what they see. *Child Development*, *59*, 703–718.

Trautmann, S. T., Vieider, F. M., & Wakker, P. P. (2008). Causes of ambiguity aversion: Known versus unknown preferences. *Journal of Risk and Uncertainty*, *36*, 225–243.

Received 26 November 2007; revised version received 16 October 2008