

Forthcoming in *Developmental Science*



## No developmental differences in preferences for epistemic versus physical uncertainty across three diverse cultures

Julia M. Smith<sup>1</sup>, Hadi Mohamadpour<sup>2</sup>, Jan Engelmann<sup>3</sup>, Helen Elizabeth Davis<sup>4</sup>, Justine Krieger<sup>3</sup>, Bettina Gro Sørensen<sup>5</sup>, Jeremy Koster<sup>6</sup>, Soomaayeh Heysieattalab<sup>2</sup>, Dorsa Amir<sup>1</sup>

1. Duke University, Department of Psychology & Neuroscience, Durham, NC 27708, USA
2. University of Tabriz, Department of Cognitive Neuroscience, Tabriz, EA 98413, Iran
3. University of California, Berkeley, Department of Psychology, Berkeley, CA 94704, USA
4. Arizona State University, School of Human Evolution and Social Change, Tempe, AZ 85281, USA
5. Texas A&M University, Department of Anthropology, College Station, TX 77843, USA
6. Department of Human Behavior, Ecology, and Culture; Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany

\*Corresponding author: Julia M. Smith, [julia.m.smith@duke.edu](mailto:julia.m.smith@duke.edu)

 <https://orcid.org/0000-0001-8788-6948>

**Conflict of Interest Statement:** The authors have no conflicts of interest to disclose.

## Abstract

We regularly make decisions under uncertainty, but the same decision can feel different when made under *physical uncertainty*, where a decision maker must guess at an outcome that has not yet occurred, and *epistemic uncertainty*, where the outcome has occurred but is unknown to the decision maker. Past research suggests that children prefer epistemic to physical uncertainty, but findings are conflicted as to whether this preference diminishes or even reverses over the course of development. We examined children's and adolescents' uncertainty preferences in three populations: urban communities in Iran ( $N = 100$ ) and the United States ( $N = 56$ ), and hunter-horticulturalist Tsimané communities in Bolivia ( $N = 54$ ). In Bolivia and the United States, children preferred epistemic uncertainty, choosing games where they guessed an unknown outcome *after* it occurred, rather than *before*. Children in Iran showed the same pattern but no significant preference. Importantly, there were no age-related differences in preferences, challenging the idea that there may be a developmental shift toward preferring physical uncertainty. The observed consistency across participants, including those with no exposure to dice, suggests cultural familiarity with these artefacts may not be a major factor influencing decisions. Future research should examine whether apparent differences in adults' and children's preferences in prior studies might reflect a difference between hypothetical and *in vivo* decision making rather than a developmental difference.

*Key words:* epistemic uncertainty, physical uncertainty, preferences, cross-cultural, dice

## 1. Introduction

Many of the decisions we make on an everyday basis are made with incomplete information. Sometimes, a situation is uncertain because the outcome we care about hasn't happened yet. We don't know if it will storm during an outdoor wedding when we're planning it or the outcome of a die roll before we roll it. This form of uncertainty — known as *physical uncertainty* — arises from the fact that the event of interest has not yet occurred (Robinson et al., 2006).

On the other hand, we may also lack information about events that have already occurred. For example, in an election, after all the votes have been cast, the outcome remains uncertain until the election has been called. Similarly, if a die is rolled under a cup without an observer seeing it, the result of the roll has been determined physically but the outcome remains unknown until the die is revealed. This type of uncertainty — where an outcome has occurred but is unknown — is called *epistemic uncertainty* (Beck et al., 2012). Here, *epistemic* refers to a state of knowledge, meaning the uncertainty pertains to our knowledge of the event, as opposed to its physical manifestation in the world.

Convergent lines of evidence suggest that people may prefer one type of uncertainty over another when making decisions, but which type is preferred seems to depend on features of the task or on the age of participants. For example, Brun and Teigen (1990) asked Norwegian adults to imagine guessing the outcomes of uncertain events including a dice toss and the winner of a soccer game. When they imagined betting on these outcomes, participants preferred to make their guesses *before* the die had been thrown or the game had been played. In other words, they preferred *physical* to *epistemic* uncertainty. These and similar results (e.g. Chow

& Sarin, 2002; Rothbart & Snyder, 1970) have been interpreted as reflecting adults' discomfort with being relatively incompetent (Heath & Tversky, 1991). That is, adults would rather bet on outcomes that are unknowable than on outcomes that can be known but about which they themselves are ignorant.

Robinson and colleagues (2009) similarly found that British adults preferred to guess the outcome of a hypothetical dice toss before the die had been thrown. They expected that children would develop an adult-like preference for physical uncertainty around age 7, when they were able to counterfactually contrast their knowledge with what they could know. However, using a real rather than hypothetical dice throw, they found that children (5 to 9-year-olds), teenagers (15-year-olds), and adults (17-year-olds) all preferred epistemic uncertainty — guessing the outcome of the dice toss *after* the die had been thrown. They frame this finding as adults behaving "like children" with live events, but it could as easily be argued that a preference for epistemic certainty is the norm, with adults only preferring physical uncertainty in chance events under specific conditions, such as in hypothetical scenarios and when there is a threat of being perceived as incompetent (Harris et al., 2011).

Whereas findings on adults' uncertainty preferences are mixed, children more consistently prefer epistemic uncertainty. They prefer to guess the location of a hidden toy *after* its hiding place has been determined, rather than before (Beck et al., 2011) and prefer to guess the number on a die after it has been rolled (Robinson et al., 2009; McColgan et al., referenced in Beck et al., 2012).

One hypothesis as to why children prefer epistemic uncertainty is that it is easier for them to imagine one outcome that may *have* occurred than to imagine multiple outcomes that *may* occur. Indeed, children report fewer possibilities

under epistemic uncertainty (Beck et al., 2012), and they are more likely to plan for multiple possibilities under physical uncertainty. For example, 4 to 8-year-old British children were more likely to place multiple trays to catch a block that could fall in one of multiple places when the location of the block hadn't yet been determined than when it had been determined but was unknown to the child (Robinson et al., 2006).

Philips and Kratzer (2024) argue that children's tendency to ignore multiple possibilities under epistemic uncertainty is due to their developing metacognitive abilities. Under physical uncertainty, children choose an anchor in the physical world: the two possible blocks that can be chosen by the experimenter. Under epistemic uncertainty, to succeed at the same task, they must choose an anchor based on their own mental state of uncertainty. Whereas older children and adults are able to represent both possible blocks as well as their uncertainty as to which was chosen, younger children still rely on outside anchors that represent the state of the world where one block has been chosen and do not represent their own uncertainty. In other words, under epistemic uncertainty, children may simulate one possible outcome and mistake it for the real outcome (Leahy & Carey, 2020). If so, epistemic uncertainty may feel more certain than physical uncertainty and thus be preferred in games where prizes can be won (see Beck et al., 2012 for a more thorough review). Because of the mixed results with adults, whether children outgrow this preference with age and, if so, why, is an open question.

Beck and colleagues (2011) compare children's overconfidence under epistemic uncertainty to fluency effects in adults. The existence of such biases suggests that even in adulthood, the ease with which we can imagine an outcome can affect our likelihood judgments. Indeed, adults' likelihood estimates tend to be more extreme the more they see uncertainty

surrounding an event as epistemic rather than physical (Tannenbaum et al., 2017). Thus, a preference for epistemic uncertainty may not be outgrown as metacognitive abilities develop but may be a stable tendency carried into adulthood, at least when the stakes are real and the outcome is based on chance.

Another as-yet-unexplored possibility is that the developmental trajectory of uncertainty preferences might vary cross-culturally. If children's preferences for epistemic uncertainty are due to the ease of imagining an outcome or on their nascent metacognitive abilities, we would not expect cultural variations in this preference. If adult preferences are more situationally variable, children around the world might diverge at some point, with some growing up to prefer physical and others growing up to prefer epistemic uncertainty. Importantly for this paper, exposure to randomization aids like dice might influence uncertainty preferences when such items are used in experimental tasks, because games have their own rules and norms which can be invoked by using the games' artefacts. Most games involving dice involve physical uncertainty such that players bet on outcomes (or have desirable outcomes in mind) before the dice are rolled. Because of this, guessing before the dice are rolled may feel like the "right" way to play. If so, children in cultures with dice might switch from preferring epistemic uncertainty to preferring physical uncertainty over the course of development, whereas children in cultures without familiarity with dice should not. However, if we observe no variation in preferences based on familiarity with dice, this would suggest that children's preferences and any developmental trends are not driven by specific artefacts but are more general.

In this report, we investigate potential cultural variation in and development of preferences for epistemic versus physical uncertainty. We adopt a cross-cultural,

developmental approach so that we can simultaneously assess (1) how these preferences develop and (2) where cultural differences arise, how children adopt the preferences of their own cultures (Amir & Bornstein, 2024; Amir & McAuliffe, 2020). To do this, we asked children and adolescents aged 6-19 in three diverse cultures (urban Iran, urban United States, and hunter-horticulturalist Bolivian Tsimané) to choose between a Roll-Then-Guess (epistemic uncertainty) and a Guess-Then-Roll (physical uncertainty) dice game.

We selected these communities based on responses to a call for cross-cultural collaborators, with the aim of including samples with varying exposure to dice. We ended up with four participant populations: two urban populations where nearly all children had seen dice (the United States and Iran) and two rural populations where no children had seen dice (Bolivia and Nicaragua; see supplement for data from Nicaragua and more detailed descriptions of field sites).

## 2. Methods

The study and primary analysis were pre-registered on AsPredicted ([https://aspredicted.org/FK9\\_VLW](https://aspredicted.org/FK9_VLW)).

### 2.1. Participants

Participants were 210 children (109 girls, 99 boys) from three cultures with different degrees of familiarity with dice. The mean age across samples was 10.81 ( $SD = 3.20$ ).

**Children of Tsimané hunter-horticulturalists** ( $N = 54$ , Ages 7 - 19, Mean  $_{age} = 12.15$ ,  $SD = 3.53$ , 26 girls, 28 boys), a semi-nomadic Indigenous group residing in the Bolivian Amazon. All participants were ethnically Tsimané.

**Children living in urban areas in Iran** ( $N = 100$ , Ages 7 - 16, Mean  $_{age} = 11.49$ ,  $SD = 2.88$ , 50

girls, 50 boys) **and the United States** ( $N = 56$ , Ages 6 - 12, Mean  $_{age} = 8.32$ ,  $SD = 1.76$ , 33 girls, 23 boys). We did not collect data on participants' ethnicity.

No participants were excluded from the analyses based on our pre-registered exclusion criteria. Due to logistic and access constraints, we did not reach our preregistered target sample sizes in Bolivia or the United States. We also conducted this study among the Indigenous Mayangna in Nicaragua, but due to inadvertent deviations from the experimental protocol, we decided to report these data in the supplement, although they replicate the findings reported here.

### 2.2. Materials

We used an identical set of materials across cultures to ensure consistency: (1) A *six-sided white die* with easily distinguishable dots on each side, (2) an *opaque cup* large enough to conceal the die after rolling to prevent participants from knowing the outcome before making their choice, and (3) *appropriate rewards* (such as stickers or candies) given to participants at the end of the experiment.

### 2.3 Procedure

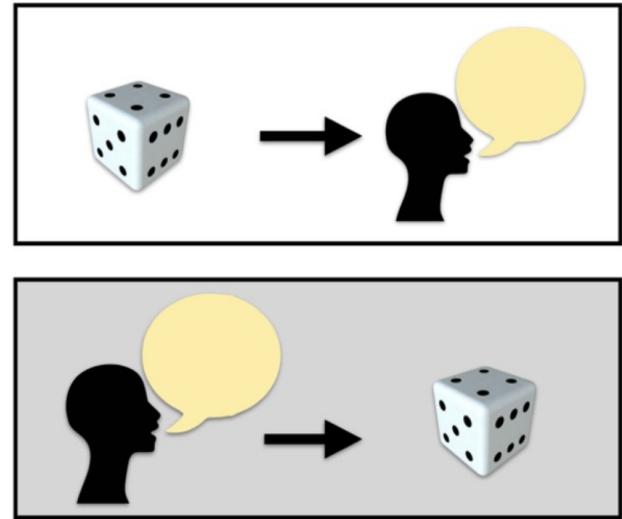
We followed a structured protocol to ensure consistency across participants and cultural contexts. Prior to the experiment, the researcher set up a video camera to capture the participant's interactions during the task. Participants' parents signed consent forms and children gave verbal assent to participate. Study protocols were approved by the IRB boards at UC Berkeley, Arizona State University, and the University of Tabriz.

The researcher began by presenting a six-sided die and inquiring if the participant had seen one before. The researcher showed each side of the die and counted the dots from one to six along

with the participant to ensure the participant understood the numbering. The researcher then demonstrated rolling the die twice, explaining that the top number determines the outcome. The participant then rolled the die twice to become familiar with rolling and identifying the outcome.

Next, the researcher explained the main task and demonstrated shaking the die in the cup, flipping it over, and looking at the result. The cup remained upside down so that the participant could not see the actual number rolled. The researcher explained that the participant would choose a number between one and six. If their chosen number matched the hidden number on the die, they would receive a reward. As a comprehension check, the researcher verified that the participant understood the winning condition and restated the explanation if the participant answered incorrectly. Most participants (79%) passed the comprehension check on the first try, and 20% passed it on the second try. Only 1% failed on both tries. All participants were included in the analyses.

Next, the researcher presented a printed diagram in counterbalanced order explaining the two game options: (1) *Roll-Then-Guess*, where the researcher rolls the die first, then the participant chooses a number and (2) *Guess-Then-Roll*, where the participant chooses a number first, then the researcher rolls the die (see **Figure 1**).



**Figure 1.** The two versions of the dice task (presented in a counterbalanced order). The top panel shows Roll-Then-Guess. The bottom panel shows Guess-Then-Roll.

The researcher conducted two *practice rounds*, one of each game version, in random order, recording the participant's guesses and the outcomes of the die rolls.

Finally, the experimenter told the participant that they were about to play the main task. There was one critical test trial: the participant chose which version of the game they preferred to play, and the researcher conducted the chosen game, recording the participant's guess and the outcome. The researcher then thanked the participant and gave them the promised reward.

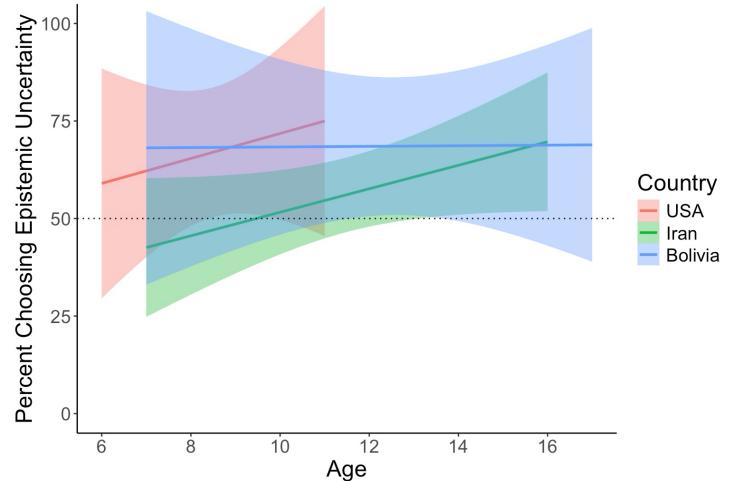
### 3. Results

Consistent with previous studies, 60.48% of participants chose the epistemic (Roll-Then-Guess) version of the game and 39.52% chose the physical (Guess-Then-Roll) version,  $X^2 = 36.92$ ,  $p < .001$ .

For our primary analysis, we fit a linear probability model predicting the binary game choice (coded as Guess-Then-Roll = 0 and Roll-

Then-Guess = 1) by age and country (both factored) using the `lm` function in R. We also ran exploratory models which included prior experience with dice and success on practice rounds. The primary analysis was preregistered. All others were exploratory.

**Primary analysis.** We found no age-related differences in game preference,  $b = 0.02$ ,  $t(206) = 1.70$ ,  $p = .090$ , or differences in game preferences by country. There was no significant difference in preferences between the United States and Iran ( $b = -0.15$ ,  $t(206) = -1.64$ ,  $p = .102$ ), the United States and Bolivia ( $b = -0.07$ ,  $t(206) = -0.704$ ,  $p = .482$ ), or Iran and Bolivia ( $b = 0.07$ ,  $t(206) = 0.90$ ,  $p = .369$ ). A model including the interaction term for age and country found no significant interactions. See Figure 2<sup>1</sup>.

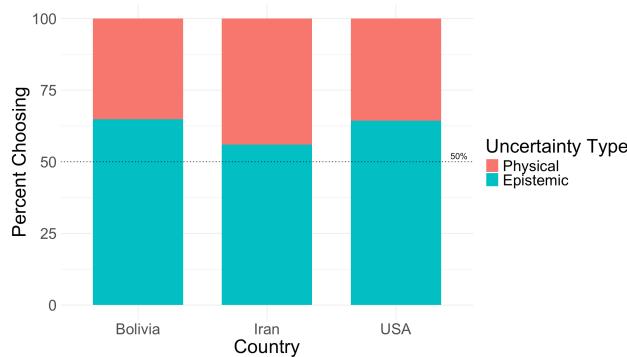


**Figure 2.** Preferences for the epistemic (Roll-Then-Guess) game by age and country. The shaded area represents the 95% confidence interval. Regression lines do not always extend to the end of the age range because some age groups consist of only one or two individuals who chose the same game (i.e. 12-year-olds in the U.S. and 19-year-olds in Bolivia.)

**Game choice in each country.** To determine whether participants preferred the epistemic game in each of our samples, we also conducted chi-squared tests for each sample. Participants in the United States, Bolivia, and Iran chose the Roll-Then-Guess (epistemic) game 64, 65, and 56% of the time, respectively. This preference was significant in the United States ( $\chi^2 = 95.48$ ,  $p < .001$ ) and Bolivia ( $\chi^2 = 95.46$ ,  $p < .001$ ) but not Iran ( $\chi^2 = 1.21$ ,  $p = .271$ ), although the pattern was the same in all research sites (see **Figure 3**).

<sup>1</sup> Note that our sample in the United States did not include children older than 12. As a robustness check, we repeated our primary analysis regressing game choice on age and country, this time restricting the age range for all countries to ages 6–12. We find the same pattern of results, with no significant effect of age ( $b = 0.02$ ,  $t(141) = 0.90$ ,  $p = .370$ ). There was a marginal difference in game

choice between the United States and Iran, such that children in Iran chose the epistemic game slightly less than those in the United States,  $b = -0.18$ ,  $t(141) = -1.93$ ,  $p = .056$ . There were no differences between the United States and Bolivia ( $b = -0.01$ ,  $t(141) = -0.08$ ,  $p = .938$ ) or between Bolivia and Iran ( $b = -0.18$ ,  $t(141) = -1.57$ ,  $p = .118$ ).



**Figure 3.** Preferences for Physical Uncertainty (Guess-Then-Roll game) and Epistemic Uncertainty (Roll-Then-Guess game) in each country.

**Dice exposure and game choice.** Whereas all children from the USA and all but one child from Iran had seen dice, none of the Tsimané children in Bolivia had seen them. Importantly for the question of cultural familiarity with dice, when we included dice exposure in the model (hadn't seen dice = 0, had seen dice = 1), we observed no significant differences in game preferences between participants who had or hadn't seen dice prior to the study,  $b = 0.49$ ,  $t(207) = 0.10$ ,  $p = .321$ .

**Practice trial performance and game choice.** Finally, we assessed the impact of practice trials on game choice. Recall that there are four possibilities when it comes to performance on the two practice trials: they guessed correctly on neither trial ( $N = 146$ ), they guessed correctly on the Roll-Then-Guess trial ( $N = 27$ ), they guessed correctly on the Guess-Then-Roll trial ( $N = 26$ ), or they guessed correctly on both trials ( $N = 8$ ). We ran a linear model predicting game choice (Guess-Then-Roll = 0, Roll-Then-Guess = 1) from practice trial performance (factor with levels “neither”, “Roll-Then-Guess”, “Guess-Then-Roll”, “both”). Guessing correctly on the Roll-Then-Guess (epistemic) practice round didn't influence participants' choices,  $b = 0.05$ ,  $t(203) = 0.54$ ,  $p = .590$ . However, participants

who guessed correctly on the Guess-Then-Roll (physical) practice trial were more likely to choose the Guess-Then-Roll game,  $b = -0.45$ ,  $t(203) = -4.59$ ,  $p < .001$ . When we re-ran our primary analysis excluding participants who matched on one practice trial but not the other ( $N = 53$ ), we found the same pattern of results, with no age-related differences ( $b = 0.01$ ,  $t(150) = 0.84$ ,  $p = .405$ ) and no differences by country. With these exclusions, participants chose the Roll-Then-Guess game 65% of the time, the same preference we observed with these observations included,  $X^2 = 3.47$ ,  $p = .062$ .

## 4. Discussion

In this study, we investigated children's preferences for physical versus epistemic uncertainty in three diverse cultural groups: Bolivian Tsimané, Iranians, and U.S. Americans. Contrary to previous findings which suggest a developmental shift in preferences from epistemic to physical uncertainty, we found a consistent preference for epistemic uncertainty across age groups. These results suggest that people might prefer epistemic uncertainty in live games of chance across development.

Notably, past research has found that adults, but not children, prefer physical uncertainty in chance events when they have some control over the outcome (Harris et al., 2011) and that adults prefer physical uncertainty in hypothetical situations (Brun & Teigen, 1990; Robinson et al., 2009). Future research should test children's preferences in hypothetical scenarios and other circumstances where adults prefer physical uncertainty to better understand when children's preferences might be sensitive to context and uncover possible developmental trends in such contexts.

We found no significant cross-cultural differences in uncertainty preferences, including among Tsimané children with minimal exposure

to dice. This suggests that exposure to such games might not be a significant factor influencing uncertainty preferences. Nevertheless, it is possible that cultural differences exist in societies not sampled in this research, or that norms within specific groups (e.g. frequent players of dice-featuring games) may influence uncertainty preferences. Additionally, although we did not find significant differences by culture, we did find that Iranian participants didn't prefer epistemic uncertainty significantly more than physical uncertainty, whereas American and Tsimané participants did. It is unclear whether children in Iran have no preference or a weaker preference for epistemic uncertainty, and more research is necessary to fully understand uncertainty preferences in this context.

Participants' success on practice trials predicted their preferences such that participants who had successfully guessed on the Guess-Then-Roll (physical uncertainty) practice trial were more likely to choose the Guess-Then-Roll game. Interestingly, guessing correctly on the already more preferred Roll-Then-Guess practice trial was unrelated to game preferences. This finding suggests new avenues for future research regarding the impact of personal history on uncertainty preferences. For example, as mentioned above, sub-populations who use dice frequently in structured settings might have extensive histories of success and failure under physical uncertainty but few experiences with epistemic uncertainty. How this may impact preferences is an open question. Of course, researchers should be cautious about unintended effects of practice trials, for example by

excluding participants who succeeded on one practice trial but not the other, as we and other researchers have done (Robinson et al., 2009).

Finally, future research should aim to recruit older children in the United States, as we were unable to do this, and should examine uncertainty preferences in younger children. In recent research that tested success on tasks requiring children to plan for multiple outcomes (catching a ball dropped into an inverted-Y-shaped-tube and preparing a snack for one of two animals that might slide down a slide), 3 to 4-year-olds succeeded at both epistemic and physical versions of the tasks (Turan-Küçük & Kibbe, under review). Whether they *prefer* one type of uncertainty to another at this age remains an open question.

The results of this research support the idea that, across diverse settings, children and adolescents tend to prefer epistemic to physical uncertainty, with no evidence of developmental shifts. As discussed previously, it is possible that both children and adults find it easier to simulate one possible outcome, and imagine it to be the correct one, than to simulate multiple outcomes simultaneously. As a result, decisions under epistemic uncertainty *seem* more certain and therefore easier to make. The circumstances under which children and adults might prefer different types of uncertainty remains an interesting avenue for future research.

## 5. References

- Amir, D., & Bornstein, M. H. (2024). Culture in Development. In *Developmental Science* (8th ed.). Routledge.
- Amir, D., & McAuliffe, K. (2020). Cross-cultural, developmental psychology: Integrating approaches and key insights. *Evolution and Human Behavior*, 41(5), 430–444. <https://doi.org/10.1016/j.evolhumbehav.2020.06.006>
- Beck, S. R., McColgan, K. L., Robinson, E. J., & Rowley, M. G. (2011). Imagining what might be: Why children underestimate uncertainty. *Journal of Experimental Child Psychology*, 110(4), 603–610.
- Beck, S. R., Robinson, E. J., & Rowley, M. G. (2012). Thinking about different types of uncertainty. *Foundations of Metacognition*, 181–192.
- Brun, W., & Teigen, K. H. (1990). Prediction and postdiction preferences in guessing. *Journal of Behavioral Decision Making*, 3(1), 17–28. <https://doi.org/10.1002/bdm.3960030103>
- Chow, C.C. & Sarin, R.K. (2002). Known, unknown, and unknowable uncertainties. *Theory and Decision*, 52, 127-138.
- Harris, A.J.L., Rowley, M.G., Beck, S.R., Robinson, E.J., & McColgan, K.L. (2011). Agency affects adults', but not childrens', guessing preferences in a game of chance. *The Quarterly Journal of Experimental Psychology*, 64(9), 1772-1787.
- Heath, C. & Tversky, A. (1991). Preference and belief: Ambiguity and competence in choice under uncertainty. *Journal of Risk and Uncertainty*, 4, 5-28.
- Leahy, B. P., & Carey, S. E. (2020). The acquisition of modal concepts. *Trends in Cognitive Sciences*, 24(1), 65–78.
- Philips, J. & Kratzer, A. (2024). Decomposing modal thought. *Psychological Review*, 131(4), 966.
- Robinson, E. J., Pendle, J. E. C., Rowley, M. G., Beck, S. R., & McColgan, K. L. T. (2009). Guessing imagined and live chance events: Adults behave like children with live events. *British Journal of Psychology*, 100(4), 645–659. <https://doi.org/10.1348/000712608X386810>
- Robinson, E. J., Rowley, M. G., Beck, S. R., Carroll, D. J., & Apperly, I. A. (2006). Children's sensitivity to their own relative ignorance: handling of possibilities under epistemic and physical uncertainty. *Child Development*, 77(6), 1642–1655. <https://doi.org/10.1111/j.1467-8624.2006.00964.x>
- Rothbart, M., & Snyder, M. (1970). Confidence in the prediction and postdiction of an uncertain outcome. *Canadian Journal of Behavioural Science*, 2(1), 38–43. <https://doi.org/10.1037/h0082709>
- Tannenbaum, D., Fox, C. R., & Ülkümen, G. (2017). Judgment extremity and accuracy under epistemic vs. aleatory uncertainty. *Management Science*, 63(2), 497–518. <https://doi.org/10.1287/mnsc.2015.2344>
- Turan-Küçük, E. N., & Kibbe, M. M. (2025, January 18). Children's reasoning about possible outcomes of events in the present and the future. <https://doi.org/10.31234/osf.io/vudfm>