Abstract

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Primary discipline: Psychology

Title: Modal reasoning abilities emerge more unified than previously assumed

Living in an uncertain world, we represent and prepare for different possibilities all the time. It may or may not rain later, so should I bring an umbrella? We may or may not have milk left in the fridge, so should I buy some while in the supermarket? When confronted with such alternative possibilities, we can experience different kinds of uncertainty: with physical uncertainty the outcome has yet to happen, while with epistemic uncertainty the outcome has happened, but is unknown. From the perspective of cognitive development – mainly ontogenetically but in principle also evolutionarily one central question is: How do the capacities to represent these types of uncertainty develop? One set of empirical findings suggests an interesting asymmetry in acquisition, which has, in turn, played an important theoretical role for accounts on the development of modal cognition. In the so-called "Doors task", Robinson et al. (2006) asked 4- to 6-year-old children to plan in light of possible outcomes of events that were either about to happen or had already happened. Children had to place trays to catch a colored block that an experimenter pushed through a door of the corresponding color. In the physical uncertainty condition, children placed the tray(s) before the experimenter drew from a bag that contained orange and green blocks. In the epistemic uncertainty condition, children placed their tray(s), after the experimenter had already covertly drawn a block (Robinson et al., 2006). To be sure to catch the block, children had to place two trays – irrespective of the type of uncertainty. However, while already 4- to 5-year-olds placed two trays in the physical uncertainty condition, even 6-year-olds struggled to do so in the epistemic uncertainty condition.

From the point of view of various theoretical accounts on modal cognition, the purported developmental asymmetry between representing physical and epistemic uncertainty has substantial theoretical repercussions (e.g., Beck et al., 2012; Gautam et al., 2019; Phillips & Kratzer, 2024). For instance, Gautam et al. (2019) explain the asymmetry in acquisition by highlighting the role of the temporal structure of the possibilities. Their account proposes that while physical uncertainty involves representing how possibilities in the *future* may unfold from the present (from here onwards, the block that is drawn may be orange or green), epistemic uncertainty involves representing possible versions of the past (in the past, the experimenter could have drawn an orange or a green block…) and the resulting different versions of the present (... and as a consequence the block may now be behind the orange or the green door). They claim that this entails different levels of recursive meta-representation and thus different levels of complexity: representing one temporal junction for physical uncertainty (from the present to possible futures), but two temporal junctions for epistemic uncertainty (from the present to possible pasts, and from there to possible futures, of which one became the actual present) (Gautam et al., 2019). These developments parallel the development of Theory of Mind – from first level to recursively embedded higher levels. Both representing physical uncertainty and representing first-order mental states (such as beliefs) are forms of meta-representation and thus co-emerge around age 4. One level up, representing epistemic uncertainty and representing second-order mental states (such as beliefs about beliefs) both are forms of second level recursive meta-representations and should thus develop in tandem at around age 6 (Gautam et al., 2019).

Given the heavy theoretical lifting that is assigned to the assumed empirical asymmetry, it is surprising how little we know about its robustness and generality. In fact, on second sight, the current empirical situation turns out to be rather complex and puzzling. Recent findings from comparative and developmental studies on modal cognition present a complicated picture with no apparent systematic pattern regarding epistemic and physical uncertainty. Against this background, the current studies aim to test for the robustness and generality of the asymmetry and its proposed relation to Theory of Mind. In the project, we explored whether reasoning about physical and epistemic uncertainty follows distinct developmental trajectories by investigating children's ability to prepare for multiple incompatible outcomes under epistemic and physical uncertainty. In two preregistered studies, we explore whether young children treat physical and epistemic uncertainty differently when preparing for incompatible possibilities in closely matched minimal contrast pairs of uncertainty conditions using a within-subjects design (*N* = 202, 3- to 6-year-old German-speaking children, 95 female, 107 male). In the task, children were shown a set-up with two slides, balls and wagons. Children prepared to catch one ball whose trajectory was either known (control trials), unknowable (physical condition) or unknown (epistemic condition) by pushing one or two wagons under the slides. We further explored whether children's performance in the uncertainty task was related to their first- and second-order false belief understanding.

Across both studies, we did not find a developmental asymmetry: children did not prepare differently for physically and epistemically uncertain outcomes. Children seemed to either consider multiple incompatible possibilities in each situation or failed to do so altogether. Moreover, performance in the uncertainty task was not positively correlated with Theory of Mind. Taken together, these findings challenge two theoretical assumptions: that physical and epistemic uncertainty pose different representational demands and that they rely on different levels of recursive embedding that are related to children's developing Theory of Mind. Instead, our studies suggest that the ability to represent incompatible possibilities more unified than previously assumed and thus stand in conceptual tension with recent theoretical work on the development of modal cognition.

906 words

References

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Preparing for different kinds of uncertainty

Material of Study 1 (online) & Study 2 (in the lab)

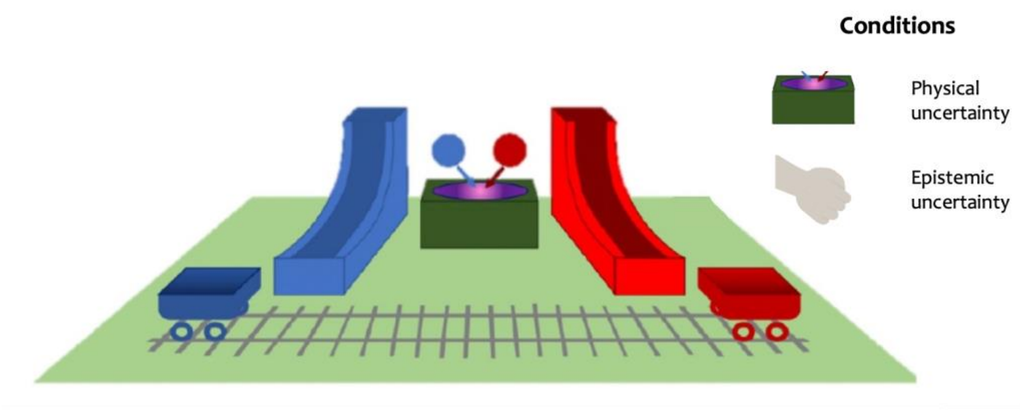

Figure 1. The At the beginning of each test trial, children watched how the experimenter put two balls (one red and one blue) into a box. Children were then asked to prepare to catch one of the balls that would come down the corresponding slide by either pushing the blue wagon, the red wagon, or both wagons under the slides. In physically uncertain trials, both balls were still in the box when children were asked to prepare. In epistemically uncertain trials, the experimenter had already covertly drawn one ball. In Study 1, the experimenter and child both lacked knowledge which ball was drawn in epistemically uncertain trials (no epistemic asymmetry). In Study 2, the experimenter knew which ball had been drawn but the child did not (epistemic asymmetry).

Results of Study 1 (*left*) & Study 2 (*right*)

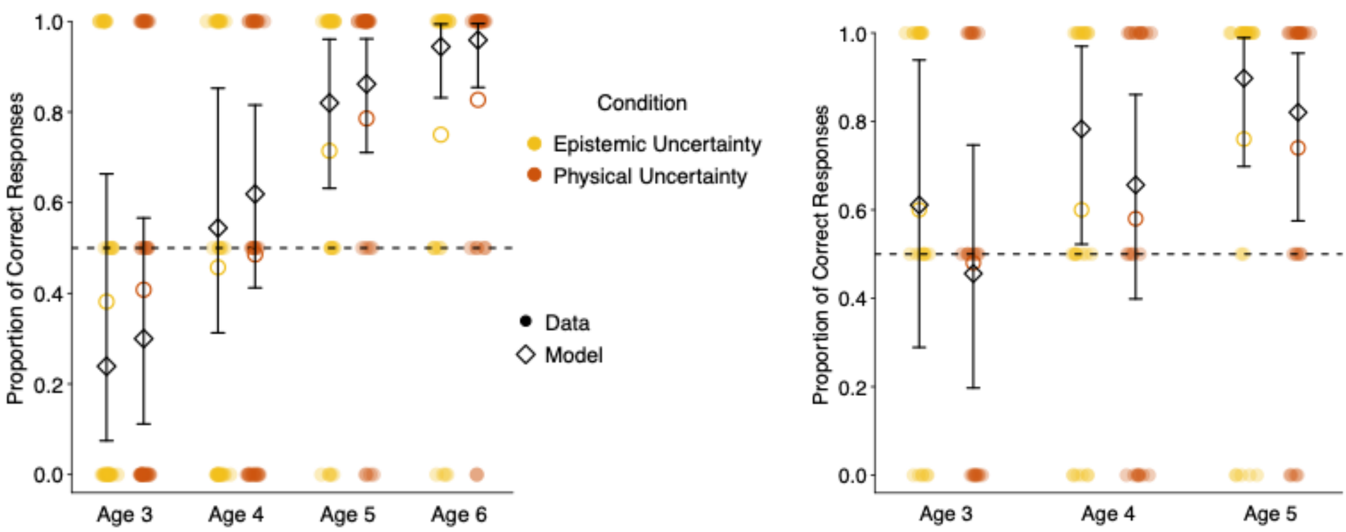

Figure 2. Outlined circles represent the observed mean proportion of correct responses. Each translucent colourful dot represents the proportion of correct responses of one participant. Diamond shapes represent the predicted probabilities for a correct response by the binomial mixed effects model, which predicted children's correct responses by condition and age. The horizontal line indicates the 50% chance level. Vertical lines indicate 95% confidence intervals. Predicted means and their confidence intervals were obtained via bootstrapping with 1000 boots. In Study 1 (*left*), we found an effect of age (b = 1.74, p = .038), but no effect of condition and no interaction. In Study 2 (*right*), found an effect of age (b = 0.81, p = .010), but no effect of condition and no interaction.