

Intuitions of probabilities shape expectations about the future at 12 months and beyond

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Rational agents should integrate probabilities in their predictions about uncertain future events. However, whether humans can do this, and if so, how this ability originates, are controversial issues. Here, we show that 12-month-olds have rational expectations about the future based on estimations of event possibilities, without the need of sampling past experiences. We also show that such natural expectations influence preschoolers' reaction times, while frequencies modify motor responses, but not overt judgments, only after 4 years of age. Our results suggest that at the onset of human decision processes the mind contains an intuition of elementary probability that cannot be reduced to the encountered frequency of events or elementary heuristics.

cognitive development | early numerical reasoning | early probability reasoning | infant cognition

The theory of probabilities is at bottom only common sense reduced to calculus; it makes us appreciate with exactitude that which exact minds feel by a sort of instinct without being able oft times to give a reason for it.

P. S. Laplace (1)

Rational agents should integrate probabilities in their predictions about uncertain future events. However, whether humans can do this, and if so, how this ability originates, are controversial issues. One influential view (2, 3) is that human probabilistic reasoning is severely defective, being affected by heuristics and biases. Another influential view (4, 5) claims that humans are unable to predict future events correctly without experiencing the frequency of past outcomes. Indeed, according to this view, in the environment in which we evolved only “the encountered frequencies of actual events” (5) were available, hence predicting the probability of an event never before observed is meaningless.

A third, largely unexplored view is that intuitions about possible future events ground elementary probabilistic reasoning (1, 6). Against this view, several classic (4, 5, 7), although not unchallenged (8), studies seemingly show that probabilistic reasoning appears late in development and requires frequency information. However, if, as Laplace wrote, probability theory “makes us appreciate with exactitude that which exact minds feel by a sort of instinct” (1), humans must have intuitions about probabilities early in their life.

Current Research

We checked whether infants have expectations about future single events never before seen, based on their likelihood. This ability may better surface when simple events reduce the difficulty of representing future states of affairs. Because infants can represent objects within the subitizing range (9) and bind them into sets (10, 11), encompassing three to four objects (12), we explored the hypothesis that at least within this limit they can also make predictions about the likelihood of future events without prior exposure to their actual frequency. We presented movies in which three identical objects and one different in color

and shape bounced randomly inside a container with an open pipe at its base, as in a lottery game [supporting information (SI) Movies 1 and 2]. After 13 s, an occluder hid the container and one object, either one of the three identical objects (probable outcome) or else the different one (improbable outcome), exited from the pipe. To avoid memory load, after 1 s the occluder was removed and all objects became visible. Because the understanding of the underlying probability distribution requires the ability to classify objects according to their properties, we tested 12-month-old infants, who can track object identities by using properties in tasks involving occlusions (13–15). Infants had no information about frequency distributions of actual outcomes, so their reactions could not be primed by previous experience. In experiment 1, after being familiarized with two “neutral” movies containing two pairs of bouncing identical objects, infants ($n = 20$, mean age 12 months, 12 days) saw four movies (two probable and two improbable) with the 3:1 object distribution (Fig. 1). Despite the complexity of the task and the lack of habituation, infants looked significantly longer when they witnessed the improbable outcome ($M_{\text{Probable}} = 9.34$ s, $M_{\text{Improbable}} = 12.55$ s; $F_{1,19} = 7.379$, $P = 0.013$).

This result suggests that infants do not need to experience outcome frequency to respond to probabilities. However, they may still respond on the basis of simple heuristics. Although the nature of heuristics has never been studied at a very early age, some simple and economical procedures unrelated to probability reasoning could be plausible candidates. For example, infants may respond to the perceptually more salient outcomes or track the minimal number of objects. Such biases could lead infants in experiment 1 to look longer at the different object outcome not because it was improbable, but because it was perceptually more salient.

Experiment 2 ($n = 20$, mean age 12 months, 12 days) addresses this possibility. We transformed the events from improbable/probable to possible/impossible, while maintaining object distributions and outcomes identical to those of experiment 1. By interposing a separator in the middle of the container, we created movies with the three identical objects confined in an area where it was physically impossible to exit (Fig. 2; SI Movies 3 and 4). Infants saw four movies, two presenting a possible outcome where the unconstrained object exited the container, and two presenting an impossible outcome where one of the confined objects exited. If infants in experiment 1 looked longer at the different object outcome not because it was improbable, but because they applied shallow perceptual or minimum effort heuristics, then in experiment 2 they should also look longer at

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