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Young children do not succeed in choice tasks that imply evaluating chances

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ABSTRACT

Preverbal infants manifest probabilistic intuitions in their reactions to the outcomes of simple physical processes and in their choices. Their ability conflicts with the evidence that, before the age of about 5 years, children's verbal judgments do not reveal probability understanding. To assess these conflicting results, three studies tested 3–5-year-olds on choice tasks on which infants perform successfully. The results showed that children of all age groups made optimal choices in tasks that did not require forming probabilistic expectations. In probabilistic tasks, however, only 5-year-olds made optimal choices. Younger children performed at random and/or were guided by superficial heuristics. These results suggest caution in interpreting infants' ability to evaluate chance, and indicate that the development of this ability may not follow a linear trajectory.

1. Introduction

Are young children able to make correct probabilistic evaluations? Infants possess probabilistic intuitions, as shown by measuring their reactions to simple physical processes, such as the exit of an object from a container: the more unlikely the exit, the more the infants tend to look at it, which is typically a sign that the event is unexpected. For example, given an urn in which three identical objects and one different in shape and color bounce randomly, 12-month-olds look longer at the display when the singleton, rather than one of the identical objects, exits from the hole at the base of the urn (Teglas, Girotto, Gonzalez, & Bonatti, 2007; Teglas et al., 2011). From the age of about 5 years, children solve judgment and choice tasks in which they have to compare the chances of two competing outcomes (for a review, see Reyna & Brainerd, 1994). For example, 5-year-olds correctly predict that one is likely to get a yellow chip, if one draws a chip at random from a bag containing 3 yellow chips and 1 blue chip (e.g., Brainerd, 1981; Girotto & Gonzalez, 2008). In other words, they make correct predictions on the basis of prior possibilities. Their correct responses do not imply that they make an explicit, numerical evaluation of the chances favoring each outcome. Yet, they suggest that young children possess a basic probabilistic knowledge. From the age of about six, children solve more difficult problems in which they have to consider additional information (e.g., Girotto & Gonzalez, 2008). For example, they correctly predict that one is likely to get a yellow chip, if one draws a chip at random from a bag containing 5 yellow chips (of which 4 are square and 1 is round) and 3 blue chips (all of which are round). Then, if they are informed that one has drawn a round chip, 6-year-olds revise their evaluation, and correctly predict that one is likely to get a blue chip. Likewise, from the age of about six, children solve probability problems in which they have to consider combinations of possibilities (Gonzalez & Girotto, 2011). For example, given a bag containing various pairs of chips, each pair having a different color, 6-year-olds correctly predict that one is likely to get two chips of different colors, if one draws two chips at random from the bag. Even preliterate and prenumerate adults are able to solve problems of this sort, and their performance is similar to that of Western, educated controls (Fontanari, Gonzalez, Vallortigara, & Girotto, 2014). Taken together, these results indicate that all individuals, regardless of their instruction and culture, share the ability to infer the probability of an event extensionally, that is, by considering the different possible ways in which it may occur (Johnson-Laird, Legrenzi, Girotto, Legrenzi, & Caverni, 1999).

In between infancy and five years of age, however, little is known about young children's probabilistic competence. The available evidence is not encouraging: 3- and 4-year-olds fail not only challenging problems that require the use of posterior evidence,

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proportions or combinatorial procedures (e.g., Girotto & Gonzalez, 2008; Gonzalez & Girotto, 2011; Piaget & Inhelder, 1975; Siegler, 1981), but also simple tasks in which they only have to consider prior information in order to predict an uncertain event. In particular, they perform poorly in simple tasks, analogous to those that have been used to investigate infants' probabilistic intuitions. For example, given a bag containing 3 yellow chips and 1 blue chip, 4-year-olds answer at chance level, if they have to predict whether a randomly drawn chip will be yellow or blue (Girotto & Gonzalez, 2008). Likewise, 3-year-olds perform at chance level, if they have to predict whether a ball, bouncing inside a rectangular box with one hole on one side and three holes on the opposite side, will exit from the one-hole side or from the three-hole one (Teglas et al., 2007/Study 3).

In sharp contrast with these negative findings, some studies have reported evidence that human infants (Denison & Xu, 2010, 2014) as well as non-human primates (Racoczy et al., 2014) possess probabilistic competence, by using choice tasks that imply evaluating chances. For example, given a jar containing 40 preferred and 10 non-preferred tokens, and a jar containing 10 preferred and 40 non-preferred tokens, 10- to 14-month-olds search in the place that hides a token drawn from the jar containing the larger number of preferred tokens (Denison & Xu, 2010, 2014). In other words, infants make optimal choices by selecting the set which is more likely to yield a preferred token. Infants make optimal choices even when they have to consider proportions. Thus, given a jar containing 16 preferred and 4 non-preferred tokens, and a jar containing 24 preferred and 96 non-preferred tokens, 10- to 13-month-olds search in the place that hides a token drawn from the jar containing the larger proportion but not the greater number of preferred tokens (Denison & Xu, 2014). In sum, preverbal participants appear to succeed in tasks in principle more demanding than those in which 3- and 4-year-olds fail. These apparently conflicting sets of results question the nature and limits of preschoolers' probabilistic cognition, and whether the development of this ability follows a linear trajectory. These questions, in turn, point to the need to test preschoolers in tasks similar to those that have provided evidence of infants' probability understanding.

Here we report three studies designed to address these questions. We used procedures inspired by the procedure designed by Denison and Xu (2010), were respondents see two sets containing various proportions of two sorts of tokens (one more attractive than the other), and must choose which set is more likely to yield an attractive token. In Denison and Xu's (2010) study, infants completed only one task. By contrast, in Study 1, children completed a series of increasingly demanding tasks. In the most elementary one, children were not required to form any probabilistic expectations because there was no uncertainty as to the outcome that each set could produce. In the most demanding tasks, in order to make optimal choices, children had to apply proportional reasoning, and resist choosing a set on the basis of superficial heuristics. Study 1 has been conducted as an independent extension and complement of Denison and Xu's (2010) study, before the publication of Denison and Xu's (2014) one, in which infants completed tasks of various difficulty levels. Study 2 investigated children's probabilistic cognition using an experimental procedure as close as possible to the one used by Denison and Xu (2014) with infants. Finally, Study 3 tested a possible alternative interpretation of the results obtained in Studies 1 and 2.

2. Study 1

In Study 1, 3- to 5-year-olds completed the tasks depicted in Fig. 1. In the simplest one (Task A), both outcomes were certain. Hence, in order to make an optimal choice, children had simply to distinguish the two sets, with no need to form probabilistic expectations. In the intermediate tasks (Tasks B), only the favorable set could yield a certain outcome. In one version (Task B1), the favorable set contained a greater number of attractive tokens than the unfavorable set. Hence, children could make optimal choices either by attributing the certainty of yielding an attractive token to the favorable set or, more simply, by using the *absolute number heuristic*, that is, selecting the set containing the greater number of attractive tokens. In another version (Task B2), the favorable set contained a smaller number of attractive tokens than the unfavorable one. Unlike the former version, in this version children had to resist selecting a set on the basis of the absolute number heuristic to make an optimal choice. In the most demanding tasks (Tasks C), both outcomes were uncertain. In one version (Task C1), the favorable set contained a greater number of attractive tokens than the unfavorable one. Hence, children could make optimal choices either by distinguishing the two sets according to their respective ratios of attractive and unattractive tokens hence, forming probabilistic expectations as to which set was more likely to yield a positive outcome or, more simply, by applying the absolute number heuristic. In another version (Task C2), the favorable set contained a smaller number of attractive tokens than the unfavorable one. Hence, children had to resist selecting a set on the basis of the absolute number heuristic to make an optimal choice.

2.1. Method

2.1.1. Participants

In Studies 1 and 2, participants were children attending public preschools in Trento (Italy). Their participation was approved by a signed consent obtained from parents. In Study 1, we tested 93 children (41 girls) distributed into three age groups: 3-year-olds ($n = 35$; mean age: 3.52; range: 2.98–4.00), 4-year-olds ($n = 33$; mean age: 4.67; range: 4.01–5.00), and 5-year-olds ($n = 25$; mean age: 5.60; range: 5.01–6.01). We tested 2 further children, but we did not consider their answer because they failed to understand the instructions.

2.1.2. Materials, procedure and design

Each child was tested individually, in a quiet room. The experimenter informed the children they would play games in which they could win some stickers. Children sat in front of a table upon which two opaque boxes ($30 \times 15 \times 10$ cm) were placed. Each box and a circular hole (10 cm in diameter) on its top, two groups of wooden chips (2 cm in diameter) colored in red or black, and two cardboards (29×21 cm), each depicting one group of chips. The boxes were placed approximately 30 cm apart. In front of each box, there was an opaque mug (10 cm in height, 4 cm in diameter). To start, the experimenter explained the rules of the game:

"We will play with these two puppets [the experimenter named and pointed at two animal-toys: an elephant and a koala]. Which one do you prefer? [The child chose one puppet] OK. Now, you and your puppet will belong to the red team. This red sticker is for you, and this red sticker is for your puppet [the experimenter distributed the stickers]. The other puppet belongs to the black team. So, I will give him this black sticker [the experimenter placed a black sticker on the other puppet].

Now, we will play with some red and some black chips [the experimenter showed some chips]. The red chips make your red team win the game. The black chips make the black team win the game. Every time you find a red chip, your red team wins a sticker. Every time you find a back chip, the black team wins a sticker."

The experimenter checked whether the children understood the instructions by asking them to name the winning color and to point to a winning chip. If they failed, she corrected them. Then, she went on: