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Brief Report

Five-year-olds do not show ambiguity aversion in a risk and ambiguity task with physical objects

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ABSTRACT

Ambiguity aversion arises when a decision maker prefers risky gambles with known probabilities over equivalent ambiguous gambles with unknown probabilities. This phenomenon has been consistently observed in adults across a large body of empirical work. Evaluating ambiguity aversion in young children, however, has posed methodological challenges because probabilistic representations appropriate for adults might not be understood by young children. Here, we established a novel method for representing risk and ambiguity with physical objects that overcomes previous methodological limitations and allows us to measure ambiguity aversion in young children. We found that individual 5-year-olds exhibited consistent choice preferences and, as a group, exhibited no ambiguity aversion in a task that evokes ambiguity aversion in adults. Across individuals, 5-year-olds exhibited greater variance in ambiguity preferences compared with adults tested under similar conditions. This suggests that ambiguity aversion is absent during early childhood and emerges over the course of development.

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Introduction

In the field of decision science, economists and psychologists formally distinguish between two types of uncertainty: risk, in which outcomes are uncertain but their probabilities are known (e.g., a 50% chance of winning $10, otherwise $0), and ambiguity, in which outcomes are uncertain and their probabilities are unknown (e.g., some unknown chance of winning $10, otherwise $0). Adult decision makers exhibit ambiguity aversion, or the preference for risky gambles over ambiguous gambles with equivalent potential outcomes. This was first demonstrated in the classic Ellsberg urn paradigm (Ellsberg, 1961), in which participants preferred to draw from a physical urn containing 50% winning and 50% losing balls over drawing from an urn containing some unknown ratio of winning to losing balls. Throughout the decades since Ellsberg's seminal work, ambiguity aversion has been consistently found in adult decision makers in a variety of different tasks (Becker & Brownson, 1964; Einhorn & Hogarth, 1986; Fox & Tversky, 1995; Hsu, Bhatt, Adolphs, Tranel, & Camerer, 2005; Yates & Zukowski, 1976; for reviews, see Camerer & Weber, 1992; Trautmann & van de Kuilen, 2015).

Many everyday decisions are formally ambiguous—even if they are colloquially described as "risky." For example, a child may know that it is "risky" to climb to the top of the jungle gym, but she does not know the exact probabilities of falling and hurting herself. Consequently, for people's everyday decisions, ambiguity preferences may be better predictors than risk preferences (i.e., preferences for certain outcomes over economically equivalent risky outcomes). In fact, two studies have found that ambiguity aversion, but not risk aversion, correlates negatively with self-reported everyday reckless behavior in older children, adolescents, and adults (Blankenstein, Crone, van den Bos, & van Duijvenvoorde, 2016; Tymula et al., 2012). Such correlations, when linked to the finding that adolescents are less ambiguity averse compared with adults (Tymula et al., 2012), have led to the conjecture that the developmental peak in reckless everyday decision making found in adolescents is driven by their tolerance for ambiguity (Shulman et al., 2016). This, in turn, suggests that public health interventions should be tailored to adolescents' ambiguity attitudes (Tymula et al., 2012).

More recent studies with younger populations, however, have found that ambiguity tolerance is not unique to adolescents. Developmental work has found that 8-year-olds are also less ambiguity averse compared with adults (Li, Brannon, & Huettel, 2015), and a cross-sectional study of participants between the ages of 10 and 25 years found ambiguity aversion to linearly increase with age, with no evidence of a quadratic trend or peak during adolescence (Blankenstein et al., 2016). Characterizing ambiguity preferences during young childhood, thus, could provide insight into its developmental time course, allowing better appreciation of later changes during adolescence and suggesting developmentally earlier opportunities for intervention to reduce maladaptive decision making. For example, the assumption that the adolescent peak in everyday reckless behavior is mirrored by laboratory risk-taking findings has been challenged by studies showing that young children take more risks compared with adolescents (Eshel, Nelson, Blair, Pine, & Ernst, 2007; Paulsen, Carter, Platt, Huettel, & Brannon, 2012; Paulsen, Platt, Huettel, & Brannon, 2011; Weller, Levin, & Denburg, 2011; for reviews, see Defoe, Dubas, Figner, & van Aken, 2015; Paulsen, Platt, Huettel, & Brannon, 2012) and highlights the need to investigate broader developmental trajectories in developmental decision-making research.

The few aforementioned currently published developmental studies of ambiguity aversion (Blankenstein et al., 2016; Li et al., 2015; Tymula, Rosenberg Belmaker, Ruderman, Glimcher, & Levy, 2013; Tymula et al., 2012) used abstract computerized stimuli to represent risk and ambiguity. Risky stimuli represented by segmented pies or bars depicting probabilities, however, may be challenging for young children to grasp before they receive formal education in probability or proportions. Furthermore, computerized ambiguous stimuli rely on visually occluded pies or bars to represent hidden probabilities (e.g., a red, blue, and gray pie with red and blue representing known probabilities and gray representing unknown probabilities). Occluded information that already represents an abstract concept of probability and that further cannot be seen requires complex verbal explanations that are likely even more difficult for young children to comprehend. Similarly, because the classic Ellsberg urn paradigm relies on verbal explanations of each urn's contents, it would likely tax the limits of young children's attention spans and working memory. Due to such methodological challenges, no studies to date have evaluated the ambiguity preferences of children younger than 8 years.

In this study, we developed a novel method of representing risk and ambiguity with physical objects that allowed us to measure 5-year-olds' ambiguity attitudes. Although previous studies have used physical objects to represent risk to 5-year-olds (Harbaugh, Krause, & Vesterlund, 2002; Levin & Hart, 2003; Schlottmann & Anderson, 1994), this is the first study to successfully present ambiguity to young children and measure consistent choice behavior.

Method

Participants

In total, 32 5-year-old children and 32 adults were recruited for the study. Two children were not tested after training trials revealed that they did not understand the task (see "Procedure" section below), leaving a final sample of 30 children (17 female; mean age = 5.5 years, range = 5.1–5.8) and 32 adults (18 female; mean age = 22.7 years, range = 18.2–31.9). Written informed consent was obtained from adult participants and the parents of child participants and verbal assent was obtained from child participants under protocols approved by the Duke University Institutional Review Board. Adults and children's parents were compensated at the rate of $10 per hour (U.S.) for their participation (all participants completed additional tasks in their sessions not reported here). Children won additional stickers and adults won additional bonus payments based on their task performance (see "Procedure" section).

Materials

In classic Ellsberg urn-style studies, risky and ambiguous stimuli are constructed by placing winning and losing colored balls into transparent (risky) and opaque (ambiguous) urns, with the urns' contents either described or labeled. For our child-friendly risk and ambiguity task, we represented winning and losing balls with plastic Easter eggs of two colors. Children were taught that all eggs of one color contained a sticker, whereas eggs of the other color were empty. Adults were taught that eggs of one color would earn them money toward a bonus payment, whereas eggs of the other color would earn no money. The winning color was counterbalanced across participants.

Risky "urns" were sheer socks containing a row of eggs, such that both the colors and number of eggs were visible. Ambiguous "urns" were opaque socks containing a row of eggs, such that the eggs' colors were obscured but the number of eggs was visible (Fig. 1). This method of representing risk and ambiguity overcomes previous challenges by allowing participants to immediately see how many eggs are in each "urn" and whether the colors of the eggs are known or unknown.

Procedure

Participants were first taught the winning (W) and losing (L) colors. All participants then passed a binary test of choosing between 1W egg and 1L egg. Next, participants were shown risky socks and taught that the contents of a chosen sock would be placed into an opaque container, from which they would randomly draw 1 egg and keep its contents. Participants completed a risky versus risky training trial (4W–2L vs. 2W–4L) and a risky versus certain training trial (5W–1L vs. 4W–0L). Two children who incorrectly chose 5W–1L over 4W–0L, demonstrating a lack of understanding of the probabilistic nature of the socks, were not further tested. Participants were then shown five example ambiguous socks and taught that they contained eggs of unknown colors, which could be all winning (4W–0L), all losing (0W–4L), or any mix of both colors (3W–1L, 2W–2L, 1W–3L).

Finally, participants completed 7 risky versus ambiguous test trials using 6-egg socks. Each possible risk level (6W–0L through 0W–6L) was presented side by side with an ambiguous 6-egg sock (also containing 6W–0L through 0W–6L) (Fig. 1). Left/Right placement of the risky/ambiguous socks and the order of the seven risky socks were presented in one of four randomizations. The order of the seven ambiguous socks was randomly selected for each session and unknown to participants as well as the experimenter. On each trial, participants' chosen sock was set aside for resolution at the end of the

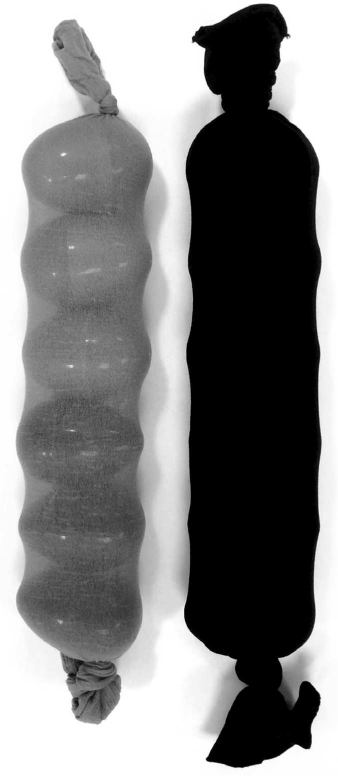

Fig. 1. Risky versus ambiguous stimuli used to test ambiguity preferences. Participants made a series of binary choices between physical stimuli representing risky gambles (in this example, 3 winning and 3 losing eggs; left) and ambiguous gambles (always containing 6 eggs of unknown colors; right).

session to prevent experienced outcomes from affecting subsequent choices. Children kept all stickers that they won by drawing from their chosen socks, whereas adults exchanged each drawn winning egg for a $0.50 (U.S.) bonus payment. For adults, the amount of bonus payment per winning egg was not revealed until the end of the session to control for individual differences in the valuation of small amounts of money.

Results

All adults and all but two 5-year-olds made consistent choices that switched from choosing risky to choosing ambiguous at a certain probability of risk, with only 3 preference reversals in the 5-year-olds' 180 trials (Fig. 2). This striking consistency indicates that children understood the task. Moreover, on the 50% risky (3W–3L) versus ambiguous trials analogous to the classic Ellsberg urn task, exactly 50% of the 5-year-olds chose risk and 50% chose ambiguity (Fig. 2A). In contrast, 65.6% of our adult sample chose risk on the 50% risky versus ambiguous trials (Fig. 2B), exhibiting levels of ambiguity aversion (one-tailed binomial test vs. chance, $p = 0.055$) similar to those previously reported in physical Ellsberg urn-style tasks (cf. 63% reported in Trautmann, Vieider, & Wakker, 2011, and 64.5%, 78.3%, and 70.7% reported in Pulford & Colman, 2008).

We next categorized participants' choice preferences (see Fig. 2C) as strongly ambiguity seeking (chose risk on ≤ 2 trials: 6 children and 1 adult), weakly ambiguity seeking (chose risk on 3 trials: 10 children and 10 adults), weakly ambiguity averse (chose risk on 4 trials: 9 children and 19 adults),

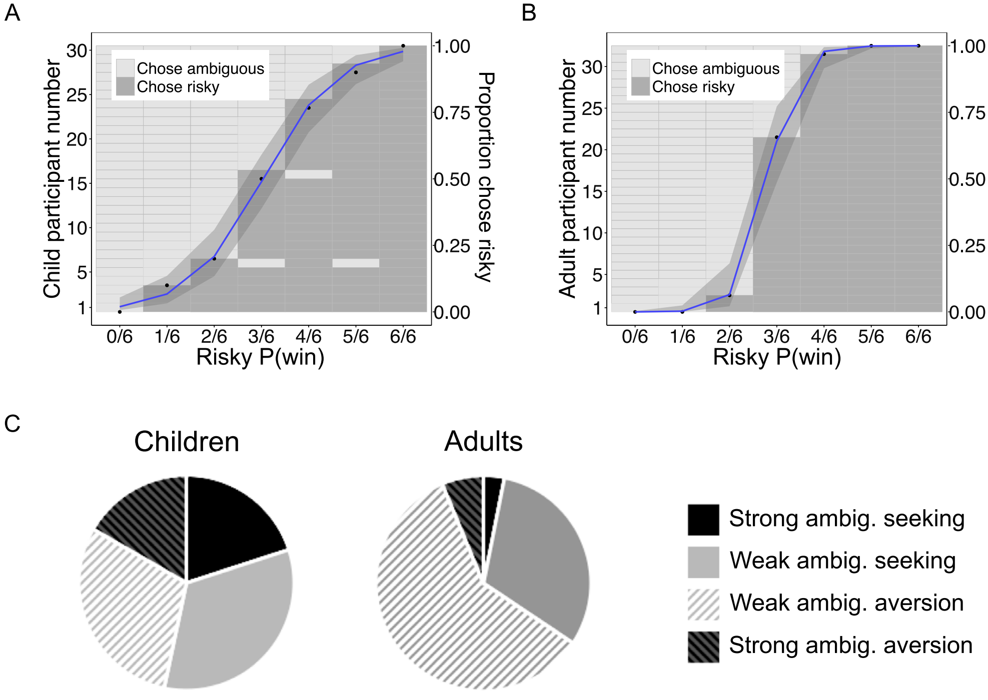

Fig. 2. Five-year-old children make consistent and ambiguity neutral choices, whereas adults are ambiguity averse. (A) Five-year-olds exhibit no ambiguity aversion, with 50% of children preferring 50–50 risk to ambiguity. Children's choices revealed striking intra-participant consistency, with only three preference reversals over all choices in the experiment. (B) Adults exhibit ambiguity aversion, with 65.6% of adults preferring 50–50 risk to ambiguity. The shaded grids depict the choices of participants (left vertical axis) at each probability of the risky sock (horizontal axis). The overlaid logistic regression line shows each group's proportion of risky choices at each risky sock (right vertical axis; shaded area around regression line indicates 95% confidence interval). (C) Categorizing children and adults as being strongly or weakly ambiguity averse or ambiguity seeking reveals different distributions between the two populations (chi-square and Fisher's exact test, $p < 0.05$). Nearly all adults exhibited weak preferences, with a majority exhibiting ambiguity aversion, whereas children were more evenly distributed between the different preference types.

or strongly ambiguity averse (chose risk on ≥5 trials: 5 children and 2 adults). Both the chi-square test, $\chi^2(3, N = 62) = 8.37$, $p = 0.03$, and Fisher's exact test ($p = 0.04$) indicated significantly different preference distributions between children and adults, with relatively more adults than children showing weak ambiguity aversion and relatively more children than adults exhibiting strong ambiguity seeking and ambiguity aversion. Thus, 5-year-olds exhibited no evidence of ambiguity aversion on a task that evoked ambiguity aversion in adults.

We note that adults were not significantly more ambiguity averse compared with children in their proportion of risky choices across all trials, $t(60) = 0.85$, one-tailed $p = 0.20$, Cohen's $d = 0.21$. This nonsignificant finding may result from significantly greater variance in children's choices compared with those of adults (Bartlett's test for homogeneity of variances, $k^2(1) = 13.82$, $p < 0.001$). In addition, adults did not choose risk significantly more often than ambiguity across all trials (52.7% chose risk, one-tailed binomial test vs. chance, $p = 0.23$). This nonsignificant finding likely results from 29 of 32 adults switching their preferences at the 50% risky sock, such that 91% of our adult sample's behavioral variability was contained solely within 1 of 7 trials. Consequently, the remaining 6 trials provided no additional preference information for nearly all of our adult sample while numerically reducing the overall proportion of risky choices.

In our adult sample, male participants were marginally more ambiguity averse (exhibited a greater proportion of risky choices across all trials) compared with female participants, $t(30) = 1.95$, $p = 0.06$. This difference was not present in our child sample, $t(28) = 0.02$, $p = 0.99$.

Discussion

Using simple physical representations of ambiguity and risk, we found 5-year-old children to exhibit no ambiguity aversion in a task that evoked ambiguity aversion in adults. Nonparametric testing on categorically defined choice preferences showed that children and adults exhibited significantly different distributions in their choice preferences. Nearly all adults exhibited weak preferences, with the majority expressing weak ambiguity aversion. Children, on the other hand, were equally likely to be ambiguity averse and ambiguity seeking, and their preferences were distributed across all categories of weak and strong ambiguity aversion and ambiguity seeking.

In our final sample, all children made correct probability-based choices in training, and all but 2 children made consistent choices without preference reversals. As a result, we are confident that 5-year-olds understood the stimuli and task and that their greater variance in choice preferences is not simply random noise. Whereas nearly all adults switched their choice from choosing risky to choosing ambiguous around the 50% risky sock, more than one third of our child sample did not. It may be that children, unlike adults, have not developed a choice heuristic based around the 50% risk level, perhaps because children lack formal education in probabilities and proportions.

We note that our task design features only a small number of trials, which is well-suited for young children but does limit the fidelity with which we can determine participants' indifference points or make statistical comparisons. Because each sock contained only 6 eggs, we can determine indifference points within only a 17% (1/6) range. For example, most of our adults (19 of 32) switched from preferring risk to preferring ambiguity between the 3W–3L and 2W–4L socks, so we know only that they value the ambiguous socks somewhere between 50% and 33% chances of winning. Thus, although our task is sufficient for detecting ambiguity aversion in adults and detecting differences in preference distributions between children and adults, it is ill-suited for quantifying degrees of ambiguity aversion. Although more fine-grained determinations of individual preferences could be made using longer socks that could fit more eggs, we note that increasing the numerical range of the stimuli (and, thus, experimental complexity) trades off against the simplicity of the task and its appropriateness for young children.

Our findings indicate that ambiguity aversion is absent in young children; however, additional work is needed to determine the features of ambiguity aversion that change over development. For example, ambiguity aversion can arise when interacting with another person who has more knowledge of outcome probabilities (Fox & Tversky, 1995) such as the experimenter who created the ambiguous stimuli. Adult studies of ambiguity aversion attempt to control for this information asymmetry and potential distrust in the experimenter by allowing participants to choose which stimulus condition leads to winning outcomes (e.g., the winning ball color; see Trautmann & van de Kuilen, 2015). The physical nature of our stimuli precluded participants from choosing their own winning color because stickers were embedded in the winning eggs (although we reiterate that we did counterbalance winning color across participants). Accordingly, our children's lack of ambiguity aversion may indicate a greater willingness to trust the experimenter. Previous work has shown that 3- to 5-year-old children quickly adapt their decision making to distrust an unreliable experimenter who promises but does not deliver toys and stickers (Kidd, Palmeri, & Aslin, 2013), so future studies could manipulate experimenter trustworthiness to determine whether that affects children's ambiguity preferences.

Ambiguity aversion could also be considered a form of pessimism, such that one assumes worse than even odds for the unknown gamble. Work with older children ($\geq$9 years) has found that the ability to learn from negative feedback and worse than expected outcomes increases with age (Cauffman et al., 2010; Moutsiana et al., 2013). Thus, ambiguity aversion may develop as children increasingly interact with an uncertain environment, within which they become better at learning from, and so increasingly expect, negative outcomes.

Finally, future work is needed to understand how ambiguity preferences of young children relate to their everyday behavior. It may be that ambiguity-tolerant young children may be just as prone to reckless behavior as adolescents, but they do not present a public health problem because of sociocultural factors restricting their freedom and access to potentially dangerous situations (Willoughby, Good, Adachi, Hamza, & Tavernier, 2013). Yet, if ambiguity tolerance is present prior to adolescence, interventions to reduce maladaptive decision making by changing ambiguity attitudes could also be targeted toward children. Alternatively, it may be that ambiguity preferences observed in economic tasks are independent from ambiguity preferences in other domains such as health and safety or social interactions (Paulsen et al., 2012; Weber, Blais, & Betz, 2002). If so, then future work should evaluate a wider range of decision-making domains in which ambiguity aversion is expressed.

Conclusions

The current study found that children do not exhibit ambiguity aversion at 5 years of age in a task that evokes ambiguity aversion in adults. Additional research is needed to test why ambiguity aversion is absent in young children, how it emerges over development, and how it interacts with everyday decision making.

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