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Mechanisms of Belief Formation in Childhood

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Abstract

How do children form beliefs from testimony? Previous work with adults suggests a "Spinozan" account of belief formation on which propositions are accepted as true by default, and rejecting them is effortful. But it is unclear whether this asymmetry between accepting and rejection propositions arises because people learn that others generally say true things or because of the cognitive architecture supporting belief formation. To distinguish between these accounts, we presented 3- to 8-year-olds with statements about a novel animal that were confirmed or denied by a knowledgeable expert. Children with poorer executive function misremembered denied statements more often than confirmed ones. A second experiment confirmed that these results did not reflect a "yes bias", and that children could select the expert's testimony over the novice's when these were pitted against each other. Together, these results suggest that rejecting statements is challenging because of the cognitive architecture supporting belief formation.

Keywords: belief formation; learning from testimony; Spinozan belief; rejection; executive function

Introduction

Young children are remarkable learners. By early childhood, children learn about their immediate physical environment, their closest social partners, and the structure of natural categories in the world. They also learn facts about the world that they could never get from direct experience—that the earth is round, that the sun is made of gas, and that the brain enables thinking. They learn these facts through testimony from others. Testimony is what makes this precocious learning about the world possible in the first place, but it also often hinders (and sometimes actively harms) learning—for example, through the spread of misinformation.

In this project, we investigate how children form beliefs from testimony. Intuitively, we might think that, upon hearing someone make a statement, we can neutrally consider the statement without accepting it as true or believing it. Then, based on available evidence or plausibility, the proposition can be either accepted (and thereby believed), or rejected. Call this account the "Cartesian" account of belief formation (Gilbert, 1991). In contrast, according to an alternative account—the "Spinozan" account—propositions cannot be neutrally considered without being believed. Propositions are believed implicitly and automatically upon being parsed or tokened. These implicitly accepted propositions can then be rejected as false, but rejection is deliberate and effortful (Gilbert, 1991; Mandelbaum, 2014; Pion et al., forthcoming, see **Figure 1**).

A study by Gilbert et al. (1990) supports the Spinozan view among adults. In this study, adults were presented with statements of the form 'Xs are Ys', followed by either a 'True' or 'False' tag. On some trials, adults were placed under cognitive load. Later, they were asked to remember whether each statement was true or false. The Cartesian account holds that statements can be neutrally entertained and that acceptance and rejection are equally effortful, and so predicts that placing participants under cognitive load would result in symmetric memory errors—they should misremember denied statements as true just as often as they misremember confirmed statements as false. However, adults misremembered statements that were false as true more often than they misremembered statements that were true as false. Crucially, this asymmetry only held for statements that participants encoded under cognitive load. Consistent with the Spinozan view, these data indicate that when cognitive resources to reject statements are scarce, adults often default to remembering them as true.

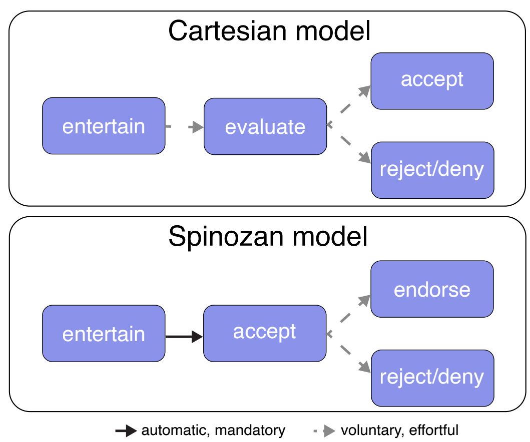

Figure 1: The Spinozan and Cartesian models of belief formation. Solid lines depict mental processes that are mandatory and automatic. Dashed lines depict processes that are voluntary and effortful.

While Gilbert et al.'s data suggest that processing rejected statements is more effortful for adults than processing affirmatives, they do not explain why. We consider two possible mechanisms that could explain why adults find rejecting statements harder. First, it is possible that, with experience, people

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learn that others tend to say true and informative things, and thus might develop a heuristic—a prior—that others will say true things. This might make it challenging for adults to reject statements as false because they need to suppress or overcome this heuristic regarding the truth of others' statements. Alternatively, adults might find rejecting statements challenging because of a more fundamental fact about the cognitive architecture that supports belief formation. On this view, the rejecting propositions is harder than accepting them because propositions are implicitly encoded as true by default, and "tagging" them as false is voluntary, deliberate, and effortful (Gilbert, 1991; Mandelbaum, 2014; Pion et al., forthcoming).

These two mechanisms make vastly different claims about the cognitive architecture that underlies belief formation, and as a result, they predict different developmental trajectories. If adults struggle to reject statements because they have learned that people tend to say true things, young children should look more Cartesian than adults—making similar memory errors for both false and true statements—and the asymmetry in their memory for false versus true statements should increase with age, as children gain more experience with truthful speakers. On the other hand, if the Spinozan account captures something more fundamental about cognitive architecture, children might need to develop the cognitive control to effectively reject statements. If this is right, memory asymmetries should be the most stark in younger children—particularly those with poorest executive function capacities, and therefore the fewest mental resources to spend on effortful belief revision.

The literature on how children learn from testimony provides mixed support for both accounts. Sometimes, children seem quite Spinozan—3- and 4-year-olds struggle to disregard misleading testimony from others, even when it contradicts their perceptual beliefs (Jaswal, 2010; Jaswal et al., 2010). Interestingly, children's ability to reject others' testimony and continue acting on the basis of their perceptual beliefs correlates with their inhibitory control capacities (Jaswal et al., 2014), just as the Spinozan account would predict.

However, other times, children seem more Cartesian. The success of Bayesian models of belief revision in capturing children's learning from testimony suggests that children rationally attend to different sources of evidence, weighing each hypothesis based on its evidence and plausibility, and picking the hypothesis that is best supported by the evidence. More direct evidence comes from cases where children effectively discount others' testimony. For example, when presented with an expert and a novice testifying about what they know, 3- and 4-year-old children attend to the expert's testimony over the novice's (Harris et al., 2018; Shafto et al., 2012). This suggests that they do not automatically encode and act on all the information they hear and can at least selectively act on an expert's testimony over a novice's.

In sum, the existing literature on how children form beliefs from testimony doesn't clearly indicate how children represent testimony and form beliefs based on it. To more directly examine the mechanisms underlying how children form beliefs from testimony, we measured children's memory for statements that were either confirmed or denied. We measured children's executive function (EF) to test whether children with higher EF skills—and therefore those who are able to spend more mental effort—are also especially good at rejecting statements they hear, as predicted by the Spinozan account. We also tested children's memory for confirmed and denied statements both immediately after they learned these statements and after a two-month delay. This design can reveal signatures of asymmetric forgetting, providing possible hints at how confirmed and rejected propositions are stored in memory. Consistent with the Spinozan account, we predicted memory asymmetries across the two sessions such that children would be more likely to misremember denied statements as true than confirmed statements as false, and that these effects would become more pronounced over time.

Experiment 1

Methods

A preregistration for our experiment is available on the Open Science Framework (OSF): https://osf.io/deaxy/overview and https://osf.io/nfj8r/overview.

Participants Our final sample consisted of 117 3- to 8-year-old children (53 boys, 63 girls, 1 non-binary; $M_{\text{age}} = 6.38$). Participants were recruited through the Princeton and NYU Discoveries in Action (PANDA) platform. Following preregistered protocols, we screened 20% of participants' videos for parental or sibling interference. Since interference rates were consistent with the rate we determined from previous work (about 1% of all trials), we retained participants' data for all trials. Our protocols and the use of human subjects for this experiment were approved by the Institutional Review Board at New York University.

Materials & Procedure This study was conducted online on the Qualtrics platform. The study was unmoderated; children completed the study at their own pace, supervised by a parent or legal guardian. Each participant included in our final sample completed two sessions (see **Figure 2**).

In the first session, children saw introductory videos that introduced them to the task, familiarization videos, and test videos. In these videos, children were introduced to two characters—an expert and a novice. They were told that the expert already knows a lot and that the novice was still learning. To convey that one of the characters was a novice, children saw videos showing the novice labeling three common items—a mug, an apple, and a chair. The novice mislabeled the mug and the chair ("That's a table."; "That's a water bottle!"), but labeled the apple correctly. Each time, the expert either confirmed their response ("Yes, that's right! That's an apple.") or denied it ("No, that's wrong! That's a chair.").

Next, children saw trials that familiarized them to the learning phase. They were told that the two characters would be learning about *modis*, a new kind of animal. They were also told that the expert already knew a lot about *modis*, while

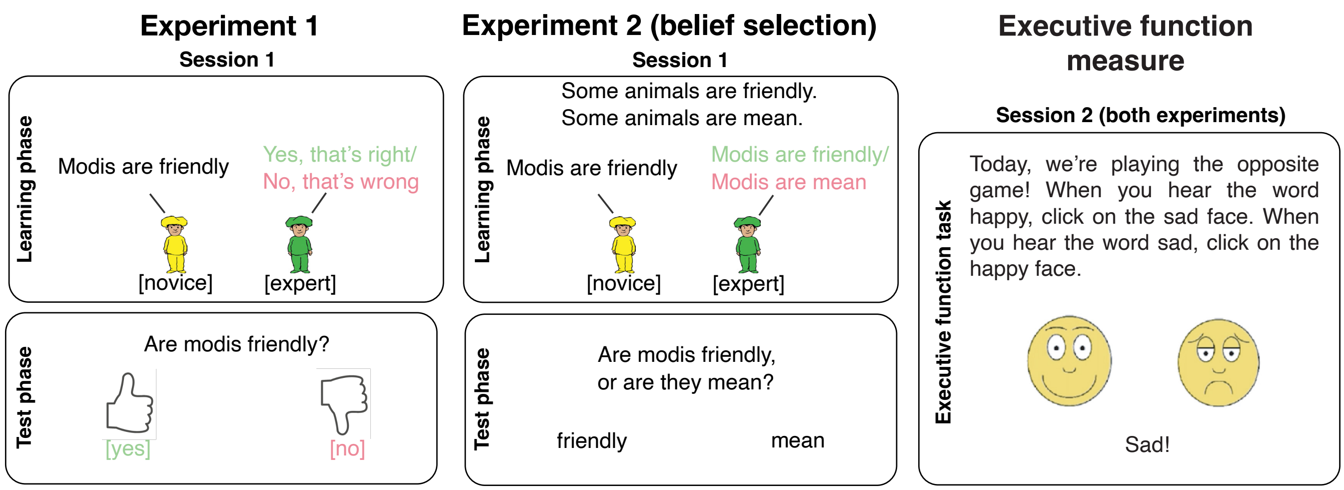

Figure 2: Procedures for Experiments 1 and the "belief selection" condition of Experiment 2. In both experiments, participants completed two sessions. In the first session of Experiment 1, children heard two characters, an expert and a novice make statements about *modis* that were either confirmed or denied by the expert. They were tested on their memory for these statements later on. Two months later, participants were invited back for a second session in which they were completed a task measuring their executive function (EF; Lagattuta et al., 2011) as an index of mental resources available for effortful rejection. Experiment 2 was similar, except that participants heard two alternative properties before the novice made a statement. In the belief selection condition, the expert either endorsed the same property the novice endorsed or the property the novice didn't endorse. In the belief rejection condition, the expert responded with either "Yes, that's right!", or "No, that's wrong!".

the novice was still learning. They saw two familiarization videos in which the novice made a statement about *modis* (e.g., "Modis have prickly fur") that the expert either confirmed or denied ("Yes, that's right!", or "No, that's wrong!"). After these trials, children were told they would learn some more facts about *modis*, and that they would need to remember what they learned later. They then moved on to the learning phase.

In the learning phase, participants saw the novice make 12 statements about *modis* (e.g., "Modis are friendly"). On each trial, the expert either confirmed or denied these statements ("Yes, that's right!" or "No, that's wrong!"). Half the statements were confirmed by the expert; the other half were denied. The order of the statements and which particular statements were denied or confirmed by the expert were randomized across participants.

After hearing the 12 statements in the learning phase, participants were asked questions about each of the statements they heard (e.g., "Are *modis* friendly?"). They responded by clicking a thumbs up (yes) or thumbs down (no) button on the screen. While a picture of a *modi* appeared when it was first introduced, no picture was visible during the learning or test phases of the experiment so that participants couldn't reference the picture when encoding facts or answering questions about them.

Two months later, participants completed Session 2 of the study. First, they were asked the same questions about modis that they answered in the test phase of the first session. Participants also completed a measure of executive function adapted from Lagattuta et al. (2011). This was used as an index of the cognitive resources they likely had available to reject statements as false. Children saw a happy and a sad face on the screen, and were told to click on a face after hearing a word. Children first completed warm-up trials in which they clicked on the face that matched the word they heard—e.g., clicking the happy face upon hearing "happy". Then, they were told they were playing the opposite game, and needed to click the face that did *not* match the word they heard; e.g., clicking the sad face upon hearing "happy". Children completed two warm-up trials for this incongruent phase in which they received feedback on their answers. Then they completed 16 test trials in which they needed to click on the face that conflicted with the word they heard. They were reminded of the instructions for the opposite game on each trial.

Results

Models were run using the `lme4` package in R (Bates et al., 2015; R Core Team, 2024). Here, we report model coefficients and *p*-values for each of the models we ran.

First, we tested whether individual differences in EF predicted whether children could accurately remember denied versus confirmed statements in Session 1. Here, EF served as a measure of the baseline cognitive resources available to children to reject statements. The Spinozan account predicts that children with the fewest cognitive resources available to reject statements (those with low EF skills) will show stronger asymmetries in memory errors between denied and confirmed statements. To test this prediction, we fit a binomial mixed-effects model predicting whether children responded correctly

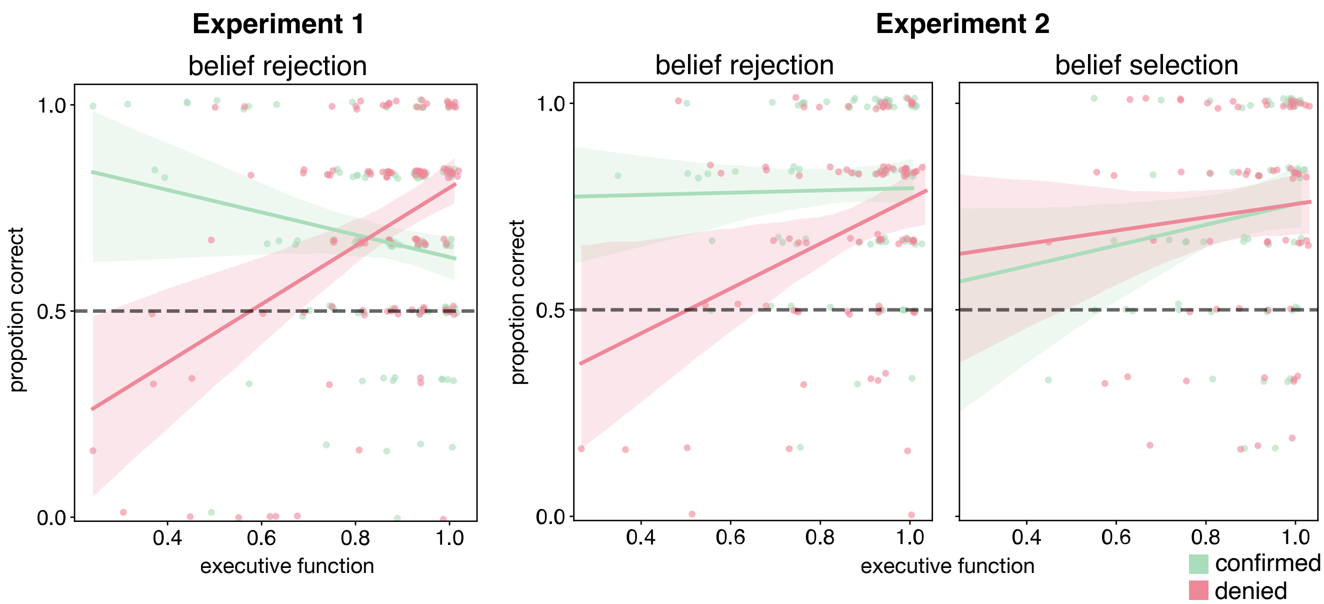

Figure 3: The proportion of correct responses in the test phases of Session 1 for Experiments 1 (left) and 2 (right), plotted against the proportion of correct responses on the test of EF in Session 2 and broken down by whether the statement was denied (red) or confirmed (green) by the expert. Each point represents one participant's proportion of correct answers for denied or confirmed statements. In Experiment 1, participants with the lowest EF scores misremembered denied statements as true more often than confirmed statements as false. Children show a similar pattern in the belief rejection condition in Experiment 2, but show no asymmetry between denied and confirmed statements in the belief selection condition.

in Session 1 based on whether each sentence was denied by the expert in the learning phase. We included EF as a predictor and controlled for age. We also included trial and participant as random intercepts. Both EF and age were mean-centered. We found no main effect of denial (β = .76, p = .186), but found a main effect of EF (β = -1.56, p = .014) such that children with higher EF scores answered more questions correctly. As predicted by the Spinozan account, we also found an interaction between memory for denied statements and participants' EF (β = 4.71; p < .001). An analysis of trends revealed a positive slope for denied statements such that memory for these statements improved with an increase in EF (b = 3.16, p < .001), and a weaker negative slope for confirmed statements such that memory for these statements decreased with improving EF (b = -1.56, p = .014; see **Figure 3**). These results are largely in line with the Spinozan account, which predicts that EF makes it easier to reject statements.

We also ran another binomial mixed-effects logistic regression model that predicted whether participants answered correctly in Session 2, including EF and denial as fixed effects while controlling for age. We included participant and trial as random intercepts. We found a main effect of denial (β = -.39, p < .001) but no main effect of EF (β = -.28, p = .577) or age (β = .00, p = .987). We also found an interaction between denial and EF (β = 1.48, p = .027). An analysis of trends revealed a significant positive slope for denied statements such that memory for these statements improved with an increase in EF (p = .017). We found no significant slope for confirmed statements (p = .577). In sum, children with higher EF were especially likely to remember denied statements correctly.

Our two-session design also allowed us to test for asymmetries in forgetting across sessions; i.e., whether children were more like to go from correctly remembering true statements in Session 1 to misremembering them as false in Session 2, or remembering false statements in Session 1 to misremembering them as true in Session 2. To do this, we collected all the statements that children remembered correctly in Session 1 and then misremembered in Session 2. An exact binomial test found that there were more denied statements in this set (.564) than confirmed ones (.436; p = .023), suggesting children find storing propositions as true easier than storing them as false.

Discussion

We tested two models of belief formation and found that the Spinozan model best explains how children form beliefs from testimony. When presented with statements from a novice that were either confirmed or denied by an expert, children with lower EF skills struggled at processing the rejection, misremembering false statements as true more often than true statements as false. These data are consistent with Gilbert et al. (1990), who showed that adults, when placed under cognitive load, show the same memory asymmetries. Both sets of findings are predicted by the Spinozan model, which holds that propositions are believed implicitly upon being tokened, and that rejecting propositions (but not accepting them) is effortful, and therefore challenging for both adults placed under cognitive load and children with poor EF skills.

However, there is an alternative explanation of our data. It is possible that children are less sure about the answers of any of the statements, and when unsure, they are biased to say "yes". Such a bias might explain children's misremembering denied statements as true across sessions—with time, children might be less certain of the statements, and choose to say "yes" to more questions. In addition to this "yes" bias, processing negation is often challenging for children, often because negative statements uttered out of context are pragmatically odd and underinformative (e.g., Nordmeyer & Frank, 2018; Reuter et al., 2018). In the absence of any pragmatically supportive context, children might find the expert's denials in Experiment 1 underinformative and therefore harder to process. Our design in Experiment 1 did not allow us to tease apart the difficulties children face in processing linguistic negation and in rejecting statements as false. We addressed these concerns in Experiment 2.

We also added a condition in which the expert and novice uttered separate statements. If children token both propositions, they might be better able to select between two beliefs that are pitted against each other than to reject a single belief.

Experiment 2

Our experiment was preregistered on the Open Science Framework (https://osf.io/uznf6/overview?view_only=ed975ec22ef54a268c24ef023ca51542). Participants were recruited through the PANDA platform. We followed the same screening protocols as in Experiment 1. Since interference rates were consistent with the rate we determined from prior work, we retained participants' data for all trials.

Methods

Participants Our final sample consisted of N=149 3- to 8-year-old children (77 boys, 72 girls, M_{age} = 6.27).

Materials & Procedure Our procedures in Experiment 2 were similar to Experiment 1 except for a few key differences (see **Figure 2**). Participants were randomly assigned to either the "belief selection" (N = 65) or the "belief rejection" (N = 84) condition. On every trial in the learning phase, participants in both conditions heard two alternative properties mentioned by a narrator (e.g., "Let's learn about how modis behave. Some animals are friendly. Some animals are mean"). Then, the novice endorsed one of these properties ("Modis are friendly"). In the belief rejection condition, the expert responded as in Experiment 1—by either confirming the novice's testimony ("Yes, that's right!") or negating it ("No, that's wrong!"). In the belief selection condition, the expert responded by either repeating the novice's testimony with confirmatory prosody (e.g., "Modis are friendly") or rejecting it by asserting the alternative, contradictory statement ("Modis are *mean*"). Participants saw 12 such trials in the learning phase.

To rule out the possibility that the "yes" bias explained children's responses, in the test phase, children were asked which of the two properties was true of modis (e.g., "Are modis friendly, or are they mean?") and were presented with two buttons that matched each of the properties mentioned. They could click one of the buttons to respond. The side of the screen on which the properties appeared was randomly determined. The property mentioned first always appeared on the left side of the screen; the second property always appeared on the right. Participants were called back for a second session one week after completing the first session. Just as in Experiment 1, in Session 2, they completed the same test phase in Session 2 without any further reminders or learning. They then completed the test of EF.

Results

Our main analysis was a binomial mixed-effects logistic regression model predicting whether participants remembered the statements in Session 1 correctly. We included as fixed effects whether the statement was denied or confirmed, the condition (belief selection or belief rejection), and the proportion of trials they answered correctly in the EF test in Session 2 as a measure of their executive function. We controlled for age as a fixed effect and included test item and participant as random intercepts.

We found a main effect of age (β = .20, p < .001) and a marginal effect of condition (β = .37, p = .075) such that participants in the negatives condition were more accurate than those in the alternatives condition. But we found no main effects of EF or denial (ps > .142), and no interactions between EF and either condition or denial (ps > .150). More importantly for our hypotheses, we found an interaction between denial and condition (β = -0.58, p = .012). We followed up with pairwise comparisons investigating the effect of denial across the two conditions. As predicted, and replicating our results from Experiment 1, children were less likely to endorse the correct property for denied statements than confirmed ones in the belief rejection condition (p < .001). This was not the case in the belief selection condition (p = .968). We also found a three-way interaction between EF, denial, and condition (β = 5.10, p = .024). To explore this interaction further, we conducted an analysis of trends separately for the belief rejection and belief selection condition. As predicted, children with lower EF were more likely to endorse the incorrect property for denied statements in the belief rejection condition but not in the belief selection condition. In the belief rejection condition, we found a positive slope for EF in predicting accurate memory of denied properties (b = 1.88, p = .012) but not for confirmed ones (b = -0.49, p = .541), suggesting that children with higher EF were especially likely to remember denied statements correctly. In the belief selection condition, we found no significant slopes for confirmed statements (b = 1.33, p = .154) or denied statements (b = .82, p = .384; see **Figure 3**). Instead, children's memory for both kinds of statements improved with age (β = .196, p = .041). In sum, children with higher EF were especially likely to remember denied statements correctly in the belief rejection condition.

But in the belief selection condition, EF did not help children in remembering either denied or confirmed statements after controlling for age.

Together, these results suggest that processing and remembering denied statements was challenging for children, but only when the expert denied the novice's statements without endorsing the alternative property. When the expert overruled the novice's testimony by endorsing an alternative proposition, as in the belief selection condition, children accurately endorsed the property the expert picked, and their accuracy for these trials did not differ from trials in which the expert endorsed the same property as the novice.

Discussion

Our results from Experiment 2 help clarify our results from Experiment 1. First, we replicated and strengthened our main finding from Experiment 1—children find it tougher to process and remember denied statements than confirmed ones in the belief rejection condition, even when the negation is pragmatically supported and informative. Notably, Experiment 2 rules out that our findings solely reflect the "yes" bias. When presented with two alternative properties, children endorsed the wrong property more often for statements the expert denied in the learning phase. Our results suggest that rejecting negated statements is particularly hard for children with low EF, consistent with Experiment 1. Second, children in the belief selection condition, in which the expert endorsed either the novice's statement or its contradictory alternative, did not show the same memory asymmetries as those in the belief rejection condition. They could appropriately select property the expert endorsed regardless of whether the expert's testimony contradicted the novice's, replicating previous work in the testimony literature (Harris et al., 2018; Shafto et al., 2012; Sobel & Kushnir, 2013).

General Discussion

We directly tested the mechanisms underlying belief formation and found that the Spinozan model best explains how children form beliefs from testimony. Overall, children find that rejecting statements and remembering them as false over time is harder than remembering statements as true.

Our results in turn allow us to better understand the findings from Gilbert et al. (1990). Gilbert et al. found that, when encoding statements under cognitive load—with limited resources available for effortful rejection—participants misremembered denied statements as true more often than they misremembered confirmed statements as false. Using a similar paradigm, we find strong parallels to Gilbert et al. (1990)'s results in our data, where children with the fewest EF capacities disproportionately misremember false statements as true more often than they misremember confirmed statements as false. Our data together with Gilbert et al. (1990)'s suggest that Spinozan rejection is more likely a consequence of how the mind encodes and rejects propositions than adults' acquiring a learned heuristic that people tend to say true things. If adults' memory asymmetries were the result of forming such a heuristic, asymmetries in memory errors would increase with age. However, our data show that, first, asymmetries in memory errors decrease with the improvement of EF and age, and second, EF is a significant predictor of memory asymmetries even when controlling for age, suggesting that the cause of memory asymmetries is a lack of cognitive resources available to reject statements rather than learning a heuristic about the truth of others' statements.

As an alternative to the idea that propositions are automatically accepted, some have proposed that people inaccurately endorse things they have heard before because such statements are easier to process when they are encountered again, and people interpret ease of processing as a signal of truth. Such fluency-based processes are unlikely to account for the present patterns, however. Fluency-based accounts predict that people will judge propositions as truer when they hear them more often. In the present study, however, children did not judge affirmed statements as truer when they encountered them twice (e.g., in the belief selection condition; "Modis are friendly"; "Modis are friendly") as compared to once (in the belief rejection condition; "Modis are friendly"; "Yes, that's right"). In fact, the means were numerically in the opposite direction than would be predicted by accounts depending on repetition.

Our data are consistent with a two-step account of belief formation. Initially, children automatically and implicitly represent propositions as true. In the second step, they can monitor the sources of testimony for their expertise, or weigh their testimony against available evidence. However, this second step is effortful and deliberative, and children with fewer mental resources disproportionately struggle with it.

Our findings also help us better understand previous conflicting data on how children learn from testimony. Children are able to rationally select between two conflicting beliefs, but struggle to reject beliefs when they should. In the belief selection condition, children select between two beliefs that they have heard. In line with prior literature (e.g., Sobel & Kushnir, 2013), children can select the expert's testimony over the novice's, and they do this equally well for confirmed and denied statements. However, children in the belief rejection condition, who hear the expert denying the novice's testimony without endorsing an alternative, cannot select between two beliefs and must instead either accept or reject one proposition. When deciding whether to endorse or reject a proposition, children often mistakenly endorse propositions they should reject. Their ability to reject statements, and therefore to form accurate beliefs from testimony, is aided by the development of mental resources that allow them to engage in effortful belief rejection. Our data suggests that belief acquisition/rejection may recruit different processes from belief selection since executive function differentially affects rejecting beliefs and selecting between them.

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