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EMPIRICAL ARTICLE

CHILD DEVELOPMENT

Disagreement reduces overconfidence and prompts exploration in young children

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Abstract

Can the experience of disagreement lead young children to reason in more sophisticated ways? Across two preregistered studies, four- to six-year-old US children ($N = 136$, 50% female, mixed ethnicities, data collected 2020–2022) experienced either a disagreement or an agreement with a confederate about a causal mechanism after being presented with ambiguous evidence. We measured (1) children's confidence in their belief before and after the (dis)agreement, and (2) how long children searched for information about the correct answer. Disagreement, especially with an expert (Experiment 2), reduced overconfidence and prompted children to search longer for information, compared to agreement. Together, our findings suggest possibilities for interventions aimed at fostering humility and learning across the lifespan.

We all seem to agree that, increasingly, we do not agree on very much. Around the world, polarization is intensifying: people disagree even on matters that would seem to be indisputable, such as the reality of climate change and the safety and efficacy of vaccines (Silver et al., 2021). The proliferation of disagreement is a concern, as it is associated with heightened political extremism and violence (e.g., Iyengar et al., 2019), and reduced mental health and psychological well-being (e.g., Coleman et al., 2014). Yet, from another perspective, disagreement can also have *positive* consequences. Thinkers such as Gandhi and Marx have highlighted conflict as an important predecessor of societal change (Roy, 1984), and, on an individual level, disagreement may prompt people to reason in more sophisticated ways (Lackey, 2010; Mercier & Sperber, 2011). The present studies explore whether certain types of disagreement can benefit cognitive development by (1) reducing young children's overconfidence in their beliefs and (2) increasing children's motivation to acquire the correct answer.

Our work is grounded in social theories of reasoning, which postulate that the human ability to reason is best understood as a fundamentally social skill, shaped by an individual's engagement in interpersonal discourse (Dutilh Novaes, 2018; Heyes et al., 2020; Kuhn, 2019; Mercier & Sperber, 2011; O'Madagain & Tomasello, 2021). While these theories generally focus on interpersonal discourse as a whole, they suggest disagreement as a particularly fruitful context for social reasoning. Specifically, disagreement might highlight diverging perspectives, motivate individuals to integrate them, and thereby result in more advanced reasoning, both in the current situation and beyond (Doise et al., 1975; O'Madagain & Tomasello, 2021). This process of cognitive conflict resolution—first identified by Piaget (1932)—is thought to influence individuals of all ages but may be particularly important early in life, given that children's thinking is characterized by a limited ability to coordinate multiple perspectives and prone to egocentrism (e.g., Foushee & Srinivasan, 2017; Piaget, 1932).

Indeed, recent research suggests that experiencing disagreement leads to a variety of beneficial outcomes. Engaging in disagreement with peers leads adolescents to produce higher-quality arguments (Kuhn, 2019) and motivates young children to provide reasons for their beliefs (see Köymen & Tomasello, 2020). Disagreement also facilitates young children's moral reasoning (Li & Tomasello, 2022) and encourages children to revise and update their beliefs rationally (Hagá & Olson, 2017;

Abbreviations: CI, confidence interval; ICC, intraclass correlation coefficient.

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Köymen & Engelmann, 2022; Langenhoff et al., 2023; Mahr et al., 2021; O'Madagain et al., 2022; Schleihauf et al., 2022). For example, one study found that, when confronted with the belief of a disagreeing other, 4- to 6-year-olds maintained their initial belief when their own evidence was stronger, adopted the other's belief when their evidence was weaker, and suspended judgment when both had equally strong evidence (Langenhoff et al., 2023).

But what is the underlying psychological process by which disagreement might elicit these cognitive benefits? We suggest that disagreement can alert a person to the possibility that they are mistaken (e.g., Christensen, 2009) and thus lead them to decrease their confidence in their initial belief and increase their interest in alternative beliefs (Lackey, 2010). Although the idea that disagreement reduces overconfidence and promotes the exploration of alternative beliefs has intuitive appeal, it has to our knowledge not been tested empirically. The present studies fill this gap by investigating the effects of disagreement on overconfidence and exploration in 4- to 6-year-olds. We focused on this age group because although overconfidence persists across the lifespan (e.g., Kruger & Dunning, 1999), children of this age are particularly prone to expressing unwarranted confidence, for example, by claiming to be "really sure" even about things that they cannot know, such as what the color "byzantium" is (Hagá & Olson, 2017; see also Lipko et al., 2009; van Loon et al., 2017). The potential effects of disagreement in reducing overconfidence could thus be especially valuable for this age group. Moreover, this is a developmental period during which children's explicit theory of mind reasoning abilities become more sophisticated (e.g., Wellman & Liu, 2004), and these developmental changes could be related to how children understand and potentially benefit from disagreements.

Understanding the effects of disagreement on overconfidence is not only important for identifying the processes that influence cognitive development, but could also play a role in informing interventions toward supporting intellectual humility (Leary et al., 2017) and learning (see Baer & Kidd, 2022; Roebers, 2017). Although possessing inflated confidence in one's beliefs may be adaptive for young learners in some cases (Hagá & Olson, 2017), the ability to accurately monitor one's confidence supports important self-regulatory processes related to learning, including allocating sufficient study time and asking for help when needed (Destan et al., 2014; Hembacher & Ghetti, 2013). Indeed, overconfidence is negatively associated with learning in both older children (e.g., Freeman et al., 2017) and adults (e.g., Dunlosky & Rawson, 2012).

Although helping young children develop a more realistic understanding of their intellectual limitations may support learning across the lifespan (see Buehler et al., 2023; Lipko et al., 2009), previous attempts to reduce overconfidence in young children have led at best to minor reductions (e.g., Buehler et al., 2023; Lipko et al., 2009; van Loon et al., 2017; van Loon & Roebers, 2020). In these studies, children were typically provided with feedback on whether their answers were correct or incorrect (i.e., performance feedback), or on the correspondence between the accuracy of their answers and their confidence judgments (i.e., metacognitive feedback; see, e.g., Buehler et al., 2023; van Loon & Roebers, 2020). One explanation for the relatively weak effects of these feedback-based interventions may be that they typically focus on the child as an individual learner, rather than on social interactions that naturally highlight the presence of alternative perspectives, as in the case of disagreement—which we focus on here.

An additional goal of the current work was to investigate whether young children's overconfidence is influenced by who they disagree with. Extensive prior research has demonstrated that when children observe disagreements among others, they pay attention to the characteristics of the disagreeing individuals and preferentially adopt the beliefs of more reliable or knowledgeable individuals over those of less reliable or knowledgeable individuals (for an overview, see Harris et al., 2018). For example, when children observe a disagreement between an expert and a novice, children are more inclined to learn from the expert than the novice (Koenig & Jaswal, 2011). Here, we were interested to see whether expertise would influence children similarly if they were involved in the disagreement themselves. Specifically, we predicted that when children experienced a disagreement with a naïve confederate (Experiment 1), they would reduce their overconfidence in their original belief only marginally, because there would be no indication that the confederate had more knowledge about the question under discussion than the child. In contrast, we expected that when children experienced a disagreement with an expert who had prior knowledge about the relevant issue (Experiment 2), children would reduce their overconfidence more significantly in light of the expert's greater prior knowledge.

Across two preregistered studies, we investigated whether disagreement reduces overconfidence and prompts exploration in four- to six-year-old children. Children and an adult confederate were exposed to ambiguous evidence about which toys make a machine play music (Figure 1). Children were then asked which toys made the machine play music and we probed their degree of confidence in their belief. Then, depending on condition, the confederate either agreed or disagreed with the child. We measured (i) changes in children's confidence in their initial belief and (ii) how long children spent searching for information about the correct answer (see Bonawitz et al., 2011; Gweon et al., 2014; Shneidman et al., 2016). In Experiment 1, children and the adult confederate had the same limited knowledge about the toys. In contrast, in Experiment 2, the adult confederate was introduced as an "expert" who knew a lot about the toys.

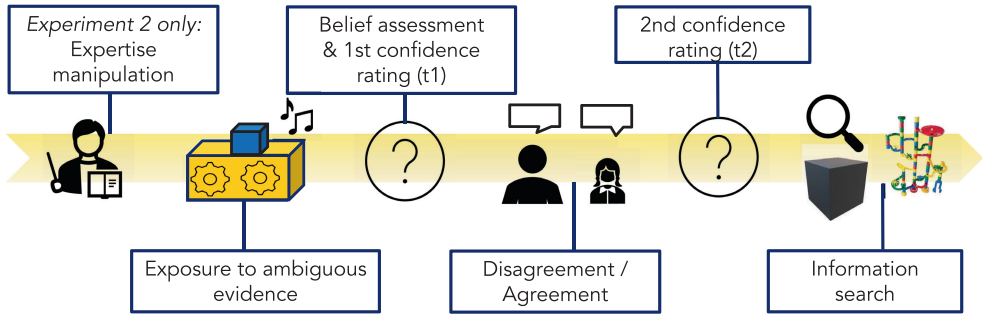

FIGURE 1 Overview of the procedures of Experiments 1 and 2.

EXPERIMENT 1

Methods

All data, analytic code, photos of study materials and the experimental protocol are publicly available on OSF and can be accessed at https://osf.io/xvkb3/?view_only=04f9b9d8cf6d4f66b26b885d6c09ad33. Both studies were preregistered on AsPredicted (Experiment 1: https://aspredicted.org?RBC_EOX; Experiment 2: https://aspredicted.org/5YP_KYR). Information regarding power analyses and exploratory measures and analyses are stated in the preregistrations and can be found in the Supplementary Materials.

Participants

Based on a power analysis (see Supplementary Materials), we tested 68 children (M_{age} = 5.43 years, SD_{age} = 0.81, 36 girls, 32 boys): 33 in the disagreement condition and 35 in the agreement condition. Children were from families with mixed socio-economic status (SES) backgrounds. Forty percent of children were white, 18% had multiple races or ethnicities, 12% were Asian, and 1% African American and Hispanic, respectively (28% of parents did not provide information about their child's race or ethnicity). Seven children were excluded in line with our preregistered exclusion criteria due to not providing a confidence judgment (N = 3), experimenter errors (N = 2), the machine malfunctioning (N = 1), or sibling interference (N = 1). Information search data were not obtained for two children due to sibling interference, so the analysis of children's information search is restricted to data from the remaining 66 children. Data for Experiment 1 were collected between January 2020 and November 2021. Children were tested either in lab, in their preschool or school, at children's museums, or at a local zoo in the San Francisco Bay Area in the United States. Children only participated if parents had provided written consent and children had provided verbal assent. Upon completion of the experiment, children received a sticker as a reward for their participation. The experiment was approved by the institutional review board of the University of California, Berkeley.

Procedure

The procedure consisted of five main stages: (1) introduction to the game and exposure to ambiguous evidence, (2) belief assessment and initial confidence rating ($t1$), (3) disagreement/agreement phase, (4) second confidence rating ($t2$), and (5) the information search phase. For an overview of the procedure, see Figure 1.

Introduction and exposure to ambiguous evidence

At the beginning of the experiment, the experimenter briefly introduced the confederate (played by one of multiple research assistants, who were all adults), by saying "This is (Name), (s)he will play with us today." After a short warm-up with a puzzle game, the experimenter announced the start of a new game. She brought out a box with her "toys," shook it, so that the participant and the confederate could hear (but not see) the toys inside, and pulled four toys out of the box, highlighting either the toys' shapes (triangle, square) or their colors (blue, green). For example, she pulled out a blue star and said, "some of my toys are blue toys, like this one." The experimenter explained that the goal of the game was to decide which of her toys were *blickets*, stating that only some toys were blickets, and others were not, and that the participant and the confederate could use her machine to figure this out. She explained that the machine would play music when a blicket was placed on it and would not play music when a toy that was not a blicket was placed on it. During the experimenter's explanations, the confederate listened attentively, to indicate that these rules were new for them, and they had no prior experience with the game. The experimenter then pretended to pull one toy out of her box at random (in fact, this toy was always a blue square) and handed it to the participant to "see if it would make the machine play music." Once the participant set the toy on the machine, the experimenter secretly pressed a remote control, which activated a bell system inside the box and caused it to play music. Next, the confederate got to place one toy on the machine. This

toy also "happened" to be a blue square and also activated the machine. Upon hearing the machine's music, the confederate exclaimed with an excited and surprised voice: "Oh, this toy is also a blicket!".

Belief assessment and initial confidence rating (t1)

The experimenter then asked the participant: "So, [child], which toys do you think are blickets? Do you think square toys are blickets? Or do you think blue toys are blickets?" (order counterbalanced). Once the participant had stated their belief about which toys were blickets, the experimenter assessed their confidence in their belief by asking "How sure are you that [square/blue] toys are blickets? Are you sure or not sure?", followed by "are you really (not) sure or just a little (not) sure?". Through this procedure, modeled after Hagá and Olson (2017), we obtained confidence ratings on a 4-point Likert scale, ranging from "1" (really not sure) to "4" (really sure).

Disagreement/agreement

Next, the experimenter asked the confederate which toys *they* thought were blickets. In the disagreement condition, the confederate *opposed* the participant's belief. For example, if the participant had said that they thought square toys were blickets, the confederate said, "I don't think square toys are blickets. I think blue toys are blickets." In the agreement condition, the confederate *confirmed* the participant's belief. Then, the confederate asked the participant to justify their belief (e.g., "Why do you think square toys are blickets?") and justified their own belief by saying, for example, "Okay, well, I think blue toys are blickets because we put two blue toys on the machine and they made the machine play music." After that, the confederate looked at their watch, said they had to leave, and left the room.

Second confidence rating (t2)

After the confederate departed, the experimenter reminded the participant of their own and the confederate's belief, and assessed the participant's confidence in their own belief for a second time, providing the same response options as described above.

Information search

Next, the experimenter brought out another, previously hidden box and shook it, so that the participant could hear that it contained a toy. The experimenter told the participant that the person who made the machine had hidden a toy in this box that was "definitely and for sure" a blicket. While placing the box a few feet away from the participant, the experimenter said that if the participant really wanted to find out which toys were blickets, they could go ahead and open the box. The experimenter then brought out a marble run (consisting of multiple elements, including a spinning wheel), placed it opposite the box and equidistant from the participant, and said that the participant could also play with "this fun marble run," or could open the box *and* play with the marble run. In reality, the box was taped up with multiple layers of transparent tape. Thus, although this was not immediately obvious, the box was actually impossible to open. The experimenter turned her back toward the participant and walked into a different corner of the room, where she pretended to be absorbed in taking notes on her clipboard. She let the participant interact with the box and/or marble run for 2 min before she returned. If the participant asked the experimenter for help or tried to interact with her in another way during this time, the experimenter stated in a neutral tone that she would be back in a bit, without responding to the help request.

Coding

We had two primary dependent variables: the *difference score of children's confidence judgments* (before [*t*1] vs after [*t*2] experiencing disagreement/agreement) and children's *information search*. To obtain each child's difference score, we calculated the difference between that child's first and second confidence rating on the four-point scale (*t*2–*t*1). This resulted in a value between −3 (indicating a shift from "really sure" to "really not sure") and +3 (indicating a shift from "really not sure" to "really sure"). To obtain the information search measure, we assessed how many seconds (out of the 2 min after the experimenter had turned around) children spent searching for additional information by engaging with the box that contained the blicket (note that per our preregistration, searching for information was defined as either physically touching or visually attending to the box; however, there were no instances in either Experiment 1 or 2 in which children simply looked at the box without manually exploring it).

Twenty-five percent of the information search data were coded for reliability by a second coder; interrater reliability was excellent (ICC = 0.99; Shrout & Fleiß, 1979; see Supplementary Materials).

Data analysis

Children's difference scores and information search data were analyzed using linear regression models (via the stats package in R; R Core Team, 2021). Our two central predictions were that (1) children of all ages would reduce their overconfidence more in the disagreement relative to the agreement condition and that (2) children of all ages would search longer for information in the disagreement, compared to the agreement condition. We were also interested in potential developmental differences in the effects of disagreement on overconfidence and information search. Specifically, prior work has shown that between ages 4 and 6, children's overconfidence decreases (e.g., Hagá & Olson, 2017), and their

explicit theory of mind reasoning abilities increase (e.g., Wellman & Liu, 2004). Given these prior findings, we wanted to be able to test whether, when confronted with disagreement, the older children in our sample would reduce their overconfidence more and search longer for information than the younger children in our sample. Thus, the main predictor in both models was the interaction between condition (disagreement vs agreement) and children's age (in years and months). Models also included children's gender and the order in which the hypotheses about blickets were mentioned (blue first and square second vs square first and blue second) as control predictors. To test for significance, we first compared each full model to a respective null model containing only the control predictors using likelihood-ratio tests (via the lrtest function from the lmtest package in R, Hothorn et al., 2015). When the full versus null model comparison was not significant, we included only the main effects for condition and age. To test the significance of individual predictors, we compared the full models with those of reduced models not containing these predictors using likelihood-ratio tests (via the drop1 function from the R stats package). Note that across experiments, none of our analyses revealed significant effects of the control predictors, so control predictor results are reported in the Supplementary Materials. Additional analyses (e.g., those related to children's justifications) can also be found in the Supplementary Materials.

Results

Children's confidence judgments

Initial belief and confidence at t1

Across conditions, almost all children immediately selected one of the two beliefs (square or blue). In line with prior work showing that children generally think shape is a good indicator of object category membership (e.g., Diesendruck & Bloom, 2003), children were somewhat more likely to think that square toys were blickets than that blue toys were blickets (disagreement condition: 60% "square"; agreement condition: 54% "square"). Children's initial belief selection did not affect their initial confidence ratings or their change in confidence from *t*1 to *t*2 (see Supplementary Materials).

On average, children in both conditions were fairly confident that their initial belief was correct, falling between "a little sure" and "really sure" (disagreement condition: $M_{t1}=3.24$ out of 4, $SD_{t1}=0.90$; agreement condition: $M_{t1}=3.26$ out of 4, $SD_{t1}=0.89$; see Figure 2). These initial confidence ratings did not differ significantly across conditions ($t_{t1}(65.60)=.068$, $p=.946$). Given that the evidence that children had observed was completely ambiguous, this meant that children in both conditions exhibited overconfidence at *t*1. In line with prior research on children's overconfidence (e.g., Hagá & Olson, 2017), we additionally found that older children were significantly less overconfident at *t*1 than younger children (see Supplementary Materials for preregistered secondary hypothesis and results).

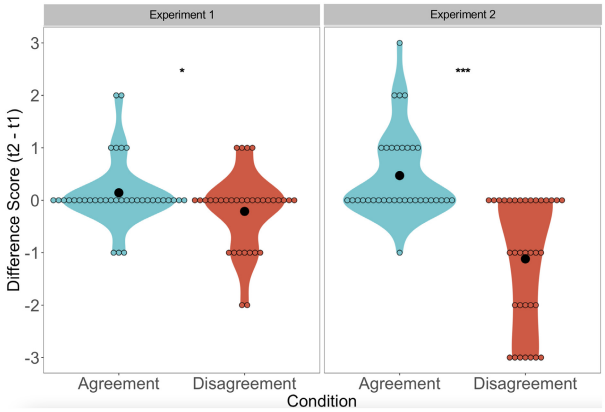

FIGURE 2 Children's difference scores in confidence (confidence at *t*2–confidence at *t*1). *Note*. The figure shows children's change in confidence in the Disagreement and the Agreement conditions of Experiments 1 (left) and 2 (right). Solid dots are condition means; empty dots are individual data points.

Changes in confidence from t1 to t2

Descriptively, from *t*1 to *t*2, children in the disagreement condition became less confident that their initial belief was correct ($M_{t2}=3.03$, $SD_{t2}=0.95$, $M_{\text{difference score}}=-0.21$, $SD_{\text{difference score}}=0.74$), while children in the agreement condition became more confident that their initial belief was correct ($M_{t2}=3.40$, $SD_{t2}=0.91$; $M_{\text{difference score}}=0.14$, $SD_{\text{difference score}}=0.65$). *T*-tests revealed that these pre- versus post-differences were not significant (disagreement condition: $t_{t1\text{ vs }t2}(34)=-1.30$, $p=.201$; agreement condition: $t_{t1\text{ vs }t2}(32)=1.65$, $p=.109$).

The preregistered linear model predicting children's difference scores from the interaction between condition and children's age was not significant when compared to its corresponding null model (χ^2 $(-3)=5.13$, $p=.162$), so we ran a model including only the main effects of condition and age, per our preregistration. This model revealed a significant effect of condition ($\beta=-.376$, 95% confidence interval (CI)=[−.721, −.032], χ^2 $(1)=4.78$, $p=.029$): as expected, children expressed significantly less confidence in a belief formed based on ambiguous evidence following disagreement compared to agreement (see Figure 2). The effect of age was not significant (χ^2 $(1)=0.002$, $p=.964$).

Children's information search

In the disagreement condition, 16% of children did not approach the box and played only with the marble run; the other 84% of children engaged in information search. Out of the children who searched, 69% searched for information *and* played with the marble run, while 31% engaged exclusively in information search. In the agreement condition, 26% of children played only with the marble run,

while the other 74% of children searched for information. Out of these children, 81% both searched for information and played with the marble run, while 19% of children searched for information only. A two-sample test for equality of proportions revealed no significant difference between the proportions of children who searched (versus did not search) for information in the disagreement versus the agreement condition (χ^2 (1) = 0.42, p = .516).

On average, children in the disagreement condition spent 66.77 s searching (SD = 43.50 s), while children in the agreement condition searched for 48.17 s (SD = 41.74 s). A t-test showed that this difference was not significant (t(62.31) = 1.77, p = .082; see Figure 3). The preregistered linear regression model predicting children's information search from the interaction between condition and children's age was not significantly different from its corresponding null model (χ^2 (−3) = 4.70, p = .200), so we ran a model including only the main effects of condition and age. Neither condition (χ^2 (1) = 2.02, p = .15) nor age (χ^2 (1) = 1.76, p = .185) revealed significant effects.

Discussion

Experiment 1 showed that young children who initially expressed unjustified confidence in a belief significantly reduced their overconfidence after experiencing disagreement (compared to agreement) with an adult. Importantly, although the youngest children in our sample were more overconfident than older children to begin with, disagreement led to similar confidence reductions across our tested age range. Children in the disagreement condition also searched longer for additional information than children in the agreement condition, but this difference was not significant.

Although children's confidence in the disagreement condition reduced significantly compared to the agreement condition, it was not significantly different from baseline ratings

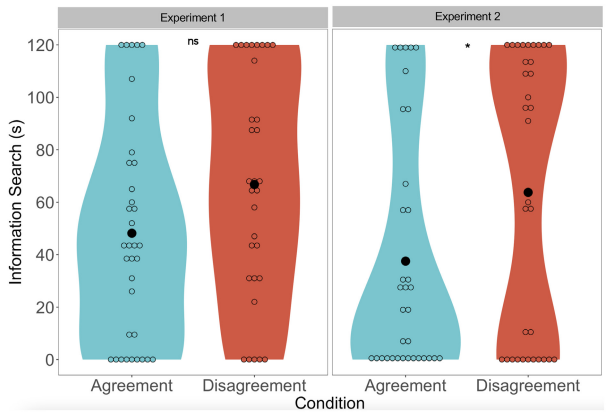

FIGURE 3 Children's information search. *Note*. Time children in the disagreement and the agreement condition spent searching for information in Experiments 1 (left) and 2 (right). Solid dots are condition means; empty dots are individual data points.

(t1), and remained in the "sure" range of the scale (i.e., above 3 on the four-point scale). Thus, children continued to exhibit overconfidence in their belief, even after disagreement. One possible explanation for why the disagreement did not have stronger effects is that it was not convincing enough: the confederate and the child had observed the same ambiguous evidence, so the confederate had no epistemic advantage over the child. In Experiment 2, we instead introduced the confederate as a "blicket expert," expecting that this would lead to a stronger reduction in overconfidence.

EXPERIMENT 2

Method

Participants

In Experiment 2, we tested a new sample of 68 children; 34 in the disagreement condition and 34 in the agreement condition (M_{age} = 5.43 years, SD_{age} = 0.79, 33 girls, 35 boys). As in Experiment 1, children were from families with mixed SES backgrounds. Twenty-seven percent of children were white, 25% had multiple races or ethnicities, 15% were Hispanic, 13% were Asian, and 3% were African American (information on race or ethnicity was not provided by 17% of parents). Four additional children were excluded because the blicket machine malfunctioned. We had to exclude the information search data for one child (due to family interference), so the analysis of the information search data is based on data from the remaining 67 children. Children for Experiment 2 were tested between February and July 2022, and recruited, tested, and compensated as in Experiment 1.

Procedure

The procedure was identical to Experiment 1, except for one key change: In both conditions, after the experimenter had stated the goal of the game (i.e., to figure out which toys were blickets), she added, "I asked [confederate] to play with us today because (s)he knows a *lot* about blickets. (S)he knows more about blickets than anyone else I know. All of her/his friends call her/him a blicket expert because (s)he knows so much about blickets." The confederate confirmed this by saying "That's right I know a *lot* about blickets." This expertise manipulation was modeled after Koenig and Jaswal (2011). Afterward, the experiment continued exactly as in Experiment 1 (Figure 1).

Coding and data analysis

The data from Experiment 2 were coded and analyzed as in Experiment 1. Twenty-five percent of the information search data were coded by a second coder, and interrater

reliability was excellent (ICC=1; Shrout & Fleiss, 1979; see Supplementary Materials). In addition, we conducted the following preregistered secondary analyses. First, in order to determine whether disagreement with an expert had stronger effects on children's overconfidence than disagreement with a confederate who had the same amount of limited knowledge as the child, we compared children's difference score data across experiments. The main predictor in this model was the interaction between experiment and condition, and age was included as an additional predictor. We were also interested to see how our two dependent variables were related. To test this, we filtered our dataset to include data from the disagreement condition only and predicted children's information search in the disagreement condition from the interaction between children's confidence at *t*2 and their age, including gender and counterbalance order as control predictors. We predicted that lower confidence ratings after experiencing disagreement with the confederate would predict longer information search.

Results

Children's confidence judgments

Initial belief and confidence at t1

In Experiment 2, children were about as likely to think that square toys were blickets as they were to think that blue toys were blickets (disagreement condition: 53% "square"; agreement condition: 53% "square"). As in Experiment 1, children's initial belief selection did not affect their confidence ratings, or their change in confidence ratings from *t*1 to *t*2 (see Supplemental Material).

Children in both conditions initially expressed strong confidence in their beliefs (i.e., they were overconfident; disagreement condition: $M_{t1}=3.53$ out of 4, $SD_{t1}=0.79$; agreement condition: $M_{t1}=3.09$ out of 4, $SD_{t1}=1.08$; see Figure 2). T1 confidence ratings did not differ significantly across conditions ($t(60.23)=-1.92$, $p=.060$). Again, we also found that the older children in our sample were initially less overconfident than the younger children (see Supplementary Materials).

Changes in confidence from t1 to t2

Unlike in Experiment 1, the confidence of children in the disagreement condition significantly decreased from *t*1 to *t*2 ($M_{t2}=2.41$, $SD_{t2}=1.26$, $M_{\text{difference score}}=-1.12$, $SD_{\text{difference score}}=1.20$, 95% CI [−1.536, −0.699], $t(33)=-5.43$, $p<.001$, $d=1.065$); so much so, in fact, that children's average confidence ratings were no longer in the "sure" range of the scale. In contrast, confidence in the agreement condition significantly increased ($M_{t2}=3.56$, $SD_{t2}=0.82$, $M_{\text{difference score}}=.47$, $SD_{\text{difference score}}=0.83$, 95% CI [0.183, 0.759], $t(33)=3.33$, $p=.002$, $d=.489$). The preregistered linear model predicting children's difference scores from the interaction between condition and age was significant compared to its null model (χ^2 (−3)=37.13, $p<.001$). A test of the individual predictors revealed no significant effect of the interaction between condition and age (χ^2 (1)=3.32, $p=.068$). A model containing only the main effects for condition and age revealed a highly significant effect of condition, as expected ($\beta=-1.590$, 95% CI [−2.086, −1.094], χ^2 (1)=33.08, $p<.001$). The effect of age was not significant (χ^2 (1)=0.86, $p=.354$).

When comparing the difference score data across experiments, the full model predicting children's difference scores from the interaction between experiment and condition was significant compared to its null model (χ^2 (−4)=53.18, $p<.001$). Specifically, there was a significant effect of the experiment × condition interaction ($\beta=-1.256$, 95% CI [−1.855, −.656], χ^2 (1)=13.28, $p<.001$). As shown in Figure 2, this effect was due to the condition difference being larger in Experiment 2, where children disagreed with an expert, than in Experiment 1, where children disagreed with a confederate who had the same amount of limited knowledge as the child. The effect of age was not significant (χ^2 (1)=0.51, $p=.475$).

Children's information search

In the disagreement condition, 33% of children did not approach the box containing the blicket; the other 67% of children did. Out of the children who searched, 59% searched for information *and* played with the marble run, while 41% engaged exclusively in information search. In the agreement condition, 38% of children did not search, while 62% of children did. Out of these children, 62% searched for information and played with the marble run, while 38% of children searched for information only. A two-sample test for equality of proportions revealed no significant difference between the proportions of children who searched (versus did not search) for information in the disagreement versus the agreement condition (χ^2 (1)=0.38, $p=.536$).

On average, children searched for 63.76 s in the disagreement condition ($SD=53.66$ s) and for 37.53 s in the agreement condition ($SD=46.02$ s; see Figure 3). A *t*-test showed that this difference was significant ($t(62.91)=2.14$; $p=.036$). The preregistered model including the interaction between condition and age was not significantly different from its null model (χ^2 (−3)=5.00, $p=.172$), but a model including only the main effects for condition and age revealed a significant effect of condition in line with our prediction ($\beta=26.613$, 95% CI [2.263, 50.964], χ^2 (1)=4.78, $p=.029$). The effect of age was not significant (χ^2 (1)=0.18, $p=.668$).

Relationship between children's confidence judgments and information search

The model predicting the information search of children in the disagreement condition from the interaction

between children's confidence at *t*2 and their age was significant compared to its null model ($\chi^2(-3) = 9.86, p = .020$). However, a test of the individual predictors revealed no significant effect of the interaction (χ^2 (1) = 0.08, $p = .774$) or the control predictors (see Supplementary Material). A model including only the main effects of children's confidence at *t*2 and their age showed a significant effect of children's *t*2 confidence ($\beta = 23.381$, 95% CI [8.639, 38.123], χ^2 (1) = 9.78, $p = .002$), revealing that children with lower confidence ratings at *t*2 searched longer for information. Age was not significant (χ^2 (1) = 1.71, $p = .191$).

GENERAL DISCUSSION

Across two preregistered studies, we tested whether experiencing disagreement–as opposed to agreement–would (1) reduce 4- to 6-year-olds' overconfidence and (2) motivate them to search for additional information regarding the correct answer. Our findings—particularly those of Experiment 2—confirmed these predictions, providing the first evidence that disagreement can reduce overconfidence in young children and prompt their search for information in adaptive ways that could benefit cognitive development.

Although younger children in our sample were initially more overconfident than older children, experiencing disagreement reduced children's overconfidence similarly across ages. Thus, unlike other interventions, such as feedback (e.g., Buehler et al., 2023), disagreement seems to be an effective tool in helping young children better calibrate their certainty. Importantly, while disagreement with an adult confederate who had the same amount of limited prior knowledge as the child (in Experiment 1) reduced children's overconfidence to some extent, only disagreement with an adult confederate who was introduced as an expert (in Experiment 2) reduced children's overconfidence significantly compared to baseline (and significantly more so than in Experiment 1). This suggests that children were sensitive to the epistemic status of whom they were disagreeing with (see Koenig & Jaswal, 2011) and did not simply reduce their overconfidence in response to an adult's greater dominance or social status. In future work, it would be interesting to examine whether children reduce their overconfidence similarly when disagreeing with naïve versus experienced peers of the same age.

We found not only that disagreement can lead children to scale back from their overconfidence but also that it can have tangible consequences, in leading children to search for additional information related to the question at hand (descriptively in Experiment 1 and statistically in Experiment 2). In showing that a central element of children's social worlds—disagreement—can prompt children's exploration in adaptive ways, our findings extend prior work on social-communicative cues that can influence children's exploration, such as pedagogical instruction (Bonawitz et al., 2011), and observing other people's surprising actions (Stahl & Woods, 2022) or emotional expressions (Wu & Gweon, 2021).

Together, our findings bridge research on explicit and implicit metacognition (see Goupil & Kouider, 2019). Prior research has usually either focused on explicit metacognition and revealed that young children are overconfident when asked to make explicit verbal confidence judgments (e.g., Hagá & Olson, 2017); or it has focused on implicit metacognition and revealed that even 2-year-olds demonstrate metacognitive sensitivity in implicit behavioral paradigms (e.g., Hembacher et al., 2020), for example, by searching longer for information in situations of greater uncertainty. The setup of the current experiments allowed us to measure explicit and implicit forms of metacognition within the same paradigm. We found in Experiment 2 that across our tested age range, children's stated confidence in their belief predicted their search behavior. Our findings thus raise the possibility that children's explicit confidence judgments can influence their intuitive and adaptive behavioral responses to uncertainty (e.g., with children searching less long for information after stating that they were "really sure").

Together, our results not only add to the burgeoning literature showing positive impacts of disagreement on children's reasoning (e.g., Li & Tomasello, 2022) but also suggest that reduced overconfidence may be an important psychological mechanism underlying some of these effects. For example, reduction in confidence may prompt the rational belief revision observed in prior studies (e.g., Langenhoff et al., 2023; Schleihauf et al., 2022) and generate information search, as in the current experiments. But why might disagreement produce these effects (both in our experiments, and more generally)? We have suggested that disagreement reduces children's overconfidence and prompts their exploration because it highlights the presence of alternative perspectives, thereby alerting children to the possibility that they might be mistaken. However, it is also possible that children might make different inferences about the personality of another person who disagrees versus agrees with them. In our experiments, for instance, children might have construed the disagreeing confederate as being unfriendly, which, in turn, may have emotionally impacted children and reduced their confidence. Although we did not directly measure children's emotional responses or their social evaluation of the confederate, children arguably would have been more likely to perceive the confederate as unfriendly in Experiment 1, where the confederate lacked any additional prior knowledge to support their contrasting belief, compared to in Experiment 2, where the confederate had a justification for their differing belief due to being more knowledgeable. Yet, we observed more pronounced effects in Experiment 2, suggesting that it was not the emotional impact of experiencing disagreement that influenced children's responses.

A related question to consider is what motivates children's increased information search after experiencing disagreement. We have suggested that children who have experienced disagreement search longer because they are less certain and thus more curious about the correct answer. This idea is supported by our finding that in Experiment 2, lower confidence at *t*2 predicted children's information search in the disagreement condition. However, given that we observed significant variability in children's information search in both Experiments 1 and 2 (see Figure 3), it is likely that other factors—in addition to increased curiosity resulting from the disagreement—influenced children's information search behaviors. For instance, in both studies, some children said they were "really sure" at *t*2, and nonetheless engaged in information search for the entire two-minute duration. These children's search may have been driven not by reduced confidence in their initial belief but by a desire to validate or affirm their *existing* belief, and to prove that they were right. Individual differences in persistence represent yet another factor that may have affected the extent of children's information search. As mentioned, opening the box to determine the true answer was very difficult (and in fact impossible), and we know from prior work that there is significant individual variation in how long young children persist at difficult tasks (Banerjee & Tamis-LeMonda, 2007; Martin et al., 2013; Mokrova et al., 2013; see also Leonard et al., 2021). In future work, the influence of these different factors could be determined by including a baseline measure of children's information search.

Including a baseline measure of children's confidence could also help to identify cases in which a decrease in confidence does not lead to an increase in information search. In our experiments, we illustrated how a reduction in overconfidence can stimulate greater information search by evoking curiosity about the correct answer. However, we expect that there will be situations in which confidence diminishes without leading to increased exploration. One example, as mentioned above, is when an individual is highly motivated to explore, not due to reduced confidence but rather because of their high confidence and their motivation to prove to others that they are right. Conversely, an individual might exhibit such low confidence that their inclination to explore becomes suppressed, as they may not believe that their own knowledge or information-seeking efforts will yield new insights (i.e., due to reduced self-efficacy). A fruitful direction of future research will be to consider how confidence and information search can be associated or dissociated across different situations.

Our studies provide initial empirical support for social accounts of reasoning which propose that human reasoning might be "at its best" in social contexts (Dutilh Novaes, 2018; Mercier & Sperber, 2011; O'Madagain & Tomasello, 2021; see also Köymen & Tomasello, 2020; Langenhoff et al., 2023; Li & Tomasello, 2022; O'Madagain et al., 2022). Notably, this proposal has been extended toward explaining the development of metacognitive reasoning, in particular (Heyes et al., 2020), which includes the ability to monitor one's (un)certainty and act upon it in reasonable ways. While the idea that individual reasoning is facilitated within social contexts—and specifically, within contexts of disagreement—is intriguing, it requires further study. Most importantly, studies are needed to probe whether the experience of disagreement has unique effects on reasoning, compared to being exposed to alternative hypotheses or additional information in a *non-social* manner (e.g., by introducing conflicting vs consistent beliefs from a non-social source, such as a robot or a computer). We are aware of two prior studies (Doise et al., 1975; O'Madagain et al., 2022) that have compared children's reasoning in a disagreement condition with their reasoning in a non-social comparison condition: both found that children benefited more from social disagreement. However, additional studies are needed to understand if and why disagreement may have these unique effects.

Our findings could hold significant potential for interventions aimed at fostering intellectual humility (Leary et al., 2017) and promoting learning (Baer & Kidd, 2022). To determine the generalizability of our findings and establish the power of disagreement-based interventions, it will be important to understand how the effects of disagreement observed here might transfer to other contexts and domains. Although our focus in the present studies was on young children, who are arguably particularly good targets of intervention (due to their overconfidence and egocentrism), disagreement-based interventions could be valuable across the lifespan, given that overestimating one's own knowledge and under-appreciating others' perspectives constitute some of the most problematic human tendencies in contemporary societies (Zmigrod et al., 2019).

Importantly, although our findings illustrate the positive consequences of disagreement, disagreement can clearly also lead to negative consequences. Disagreements are inherently social processes, and so an individual's social motives, biases, and stereotypes can likely influence how they respond to a disagreement. For example, when a person experiences disagreement regarding a belief that really matters to them, they will likely be more hesitant to reduce their confidence in that belief (see Kahan, 2017; Oktar & Lombrozo, 2022). In fact, some evidence suggests that such disagreements can sometimes even *strengthen* individuals' prior beliefs (e.g., Nyhan & Reifler, 2010). Moreover, constructive disagreements require that the disagreeing parties treat each other with respect and give each other the credibility they deserve. When individuals are not receptive to the alternative beliefs of another due to prejudices or stereotypes, disagreement will likely fail to elicit positive consequences (see Fricker, 2007). Identifying the features of disagreement that support intellectual

humility and learning will be crucial for the effective design of interventions that facilitate learning and mutual understanding.

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DATA AVAILABILITY STATEMENT

All data, analytic code, photos of study materials and the experimental protocols are publicly available on OSF and can be accessed at https://osf.io/xvkb3/?view_only=04f9b9d8cf6d4f66b26b885d6c09ad33. Both studies were preregistered on AsPredicted (Experiment 1: https://aspredicted.org/RBC_EOX; Experiment 2: https://aspredicted.org/5YP_KYR). Information regarding power analyses and exploratory measures and analyses are stated in the preregistrations and can be found in the Supplemental Material.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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