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Where Should I Search Next? Messages Embedded in Storybooks Influence Children's Strategic Exploration in Turkey and the United States

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Despite the vital role of curiosity-driven exploration in learning, our understanding of how to enhance children's curiosity remains limited. Here, we tested whether hearing a *strategic curiosity* story with curiosity-promoting themes (e.g., strategically approaching uncertainty, adapting flexibly to new information) versus a *control* story with traditional pedagogical themes (e.g., following rules, learning from others) would influence children's strategic exploration across two cultures. Three- to 6-year-olds from the United States ($N = 138$) and Turkey ($N = 88$) were randomly assigned to hear one of these stories over Zoom, before playing a game in which they searched for sea creatures across five fish tanks. All tanks had the same number of hiding spots but varied in the number of creatures they contained. Time was limited and children could not return to prior tanks, pushing them to allocate search effort strategically. Results indicated that across both countries, children in the strategic curiosity condition explored the virtual "aquarium" more broadly; they moved through tanks more rapidly than children in the control condition and were more likely to explore all five tanks before time ran out. Children in the strategic curiosity condition also showed relatively more strategic search, adapting their search based on the likelihood of finding creatures in each tank. While further research is needed to pinpoint which elements of our stories produced differences in search behavior and whether they did so by enhancing or inhibiting children's strategic exploration, storybooks appear to be a promising method for shaping children's exploration across multiple countries.

Public Significance Statement

Exploration makes young children highly proficient learners, but with age, exploration tends to become more narrowly focused on practical gains—sometimes at the expense of learning. It is critical to investigate how to encourage children to explore more broadly and strategically when this is helpful for their learning. We tested whether hearing a story with curiosity-promoting themes (e.g., approaching uncertainty) compared to a story with traditional pedagogical themes (e.g., rule following) could alter exploration among 3- to 6-year-olds from two countries (the United States and Turkey). After hearing the curiosity-promoting story compared to the more traditional one, children in both countries tended to explore a virtual environment more broadly and strategically. The results indicate that storybooks can influence children's exploration across multiple cultural contexts, suggesting that caregivers should consider what kinds of themes regarding learning, problem solving, and exploration are embedded in the stories they share with their children.

Keywords: explore-exploit trade-off, cognitive development, curiosity, children, active learning

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This study was preregistered at the Open Science Framework in August 2021. The preregistration and analytic plan can be accessed at https://osf.io/48x6f. De-identified data, R analysis script, and study materials have been made publicly available and can be accessed at https://osf.io/5sq3c/?view_only=0e96ad8f1f4e40f9a0a298254a3ab3fe. Any deviations

continued

Anyone who has seen the excitement of a toddler exploring a new toy can appreciate that curiosity is an integral feature of childhood. Young children are driven to learn about the world around them, whether by requesting information from others (Lucca & Wilbourn, 2018) or by exploring their surroundings (Jirout & Klahr, 2012). Curiosity is an important engine of learning and has been positively linked to children's academic achievement (Gualtieri & Finn, 2022; Shah et al., 2018). However, little research has examined whether it is possible to intervene to boost children's curiosity (Schutte & Malouff, 2023), and there are concerns that messages traditionally emphasized in classrooms (e.g., following instructions to get correct answers) might fail to promote curiosity-driven inquiry and exploration (Evans et al., 2023; Jirout et al., 2018). Here, we aim to fill this gap by investigating whether children's curiosity is malleable and how it might be shaped by verbal messages about learning and problem solving. Across two countries (the United States and Turkey), we test whether curiosity-promoting messaging (focused on uncertainty and strategic adaptation to the environment), compared with more traditional pedagogical messaging (focused on following rules and instructions; Gol-Guven, 2009; Russell, 2011), influences children's exploration.

Exploration Across Development

Children often express their curiosity through exploration—interacting with the environment to learn new information or fill knowledge gaps (Berlyne, 1966; Loewenstein, 1994). Examining when and how children explore across different environments has yielded insights into the motivations for their exploration and its importance for learning, in terms of both exploration breadth and its strategic (rather than random) deployment.

Exploration Breadth

Both children and adults often face a trade-off between branching out to explore opportunities with unknown outcomes and taking advantage of known opportunities—the so-called explore/exploit dilemma (Mehlhorn et al., 2015). Across a range of research paradigms, children have been found to explore more broadly than adults and be more willing to forego opportunities to "exploit" for the sake of discovering something new (e.g., Blanco & Sloutsky, 2021; Liquin & Gopnik, 2022; Lloyd et al., 2023). For instance, in bandit tasks (where multiple "machines" vary in their probability of yielding rewards), children continue trying different machines long after most adults have converged on exploiting the most rewarding one (Blanco & Sloutsky, 2021; Sumner, Steyvers, & Sarnecka, 2019). Critically, this is not due to an inability to identify the most rewarding option—as early as age 3, most children can do this successfully when asked (Blanco & Sloutsky, 2021; Sumner, Steyvers, & Sarnecka, 2019).

This developmental narrowing of exploration has been likened to the physical process of annealing, wherein materials are melted to maximize flexibility and then molded into a stable shape as they cool. Simulated annealing algorithms apply this concept to problem solving: an initially "high-temperature" search samples information from a broad swath of the search space, and gradually "cools" and narrows in on a specific region or solution (Giron et al., 2023; Kirpatrick et al., 1983). In this analogy, children's drive to explore a broader range of possibilities might be less efficient and more costly than adults' in terms of finding and using the best solution, but it is more flexible and has a higher probability of accurately learning the features of an environment (Gopnik et al., 2017). This is particularly true when an environment changes over time, and continued broad exploration helps detect these changes (Blanco et al., 2023; Mehlhorn et al., 2015). The theoretical link between exploration breadth and learning is bolstered by evidence that children are more likely than adults to detect change in reward contingencies during a bandit task (Sumner, Li, et al., 2019) and that broader exploration during a learning task is associated with more accurate learning of the task structure (Liquin & Gopnik, 2022). Furthermore, adults who are asked to learn as much as possible during a bandit task (rather than maximize rewards) tend to broaden their exploration (Sumner, Steyvers, & Sarnecka, 2019).

Strategic Exploration

While young children tend to explore broadly, they do not explore at random. Children as young as 18 months show awareness of the costs and benefits of their actions, and they expend time and effort strategically based on their perceptions of the environment (Kidd et al., 2013; Lucca et al., 2020). Of particular relevance here, preschool children make strategic decisions when allocating effort to exploring their surroundings—allocating more effort when they have reason to believe there are benefits (e.g., learning potential) in doing so. For instance, they search more persistently for an object when there is more uncertainty about its identity (Ruggeri et al., 2023), engage in more information seeking to verify a claim after exposure to unreliable information (Orticio et al., 2023), and reask questions more persistently if they do not get an informative answer (Frazier et al., 2009).

Uncertainty is especially powerful in directing children's exploration, possibly because it indicates where information is likely to be gained and curiosity is likely to be satisfied (Baer & Kidd, 2022; L. E. Schulz & Bonawitz, 2007; Sim & Xu, 2017;

from the preregistered analytical plan are described in the Supplemental Materials. Results from this study were presented at the 2024 Cognitive Development Society meeting in Pasadena, California.

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Stahl & Feigenson, 2015; Wang et al., 2021). Children are often drawn to explore uncertainty even when this has costs—as seen in bandit tasks, where exploring uncertain options often means forfeiting the chance to exploit known sources of reward (Blanco & Sloutsky, 2021; Giron et al., 2023; Meder et al., 2021). Importantly, directing exploration to resolve uncertainty does not inevitably narrow its scope. In bandit tasks, for instance, children tend to explore more broadly than adults partly because they are drawn to explore options with less certain outcomes (e.g., ones they tried less recently or whose reward probability is hidden; Blanco & Sloutsky, 2021). Children's drive to explore uncertainty, in short, can help them strategically broaden their exploration by signaling when there is information to be gained by doing so.

Uncertainty and corresponding learning potential, however, are not the only relevant considerations for making strategic exploratory decisions. Factors including time constraints, efficiency, and the practical utility and valence of new information can also shape decisions about when and what to explore (Blanco & Sloutsky, 2024; Molinaro et al., 2023). With age, the role of these various parameters appears to shift as exploration becomes less uncertainty-driven and more reward-motivated (e.g., Giron et al., 2023; but see Molinaro et al., 2023). Older children and adults are less likely than young children to explore an uncertain option when there is a more certain rewarding alternative (Giron et al., 2023; Meder et al., 2021; Nussenbaum et al., 2022). Practical utility of information also becomes more central to exploratory decisions with age (Molinaro et al., 2023). These developmental changes might be explained by the strengthening of cognitive capacities that help individuals track patterns, integrate multiple decision-making parameters, and focus on specific aspects of a search space (Blanco et al., 2023; Blanco & Sloutsky, 2020; Cogliati Dezza et al., 2019; Schulz et al., 2019). Shifting goals and priorities, however, also likely play a role. Learning the nuances of a new environment is less essential for adults—who already have a broad understanding of the world and heuristics they can apply—than for children who are still learning foundational principles (Gopnik, 2020). In short, children might not just be less able to track practical utility and weigh this against other decision parameters but might also be more motivated to resolve uncertainty and learn about new search spaces.

Enhancing Children's Exploration

Although the most dramatic developmental differences in exploration have been observed between children and adults, exploration shows evidence of narrowing as early as ages 4–6 (Blanco & Sloutsky, 2024; Gopnik et al., 2017; Sumner, Steyvers, & Sarnecka, 2019). This can have negative consequences for learning and problem solving. In particular, narrowing exploration can make individuals prone to "learning traps," wherein they come to an erroneous understanding of a task or problem space because they neglect to explore it fully (Blanco et al., 2023; Liquin & Gopnik, 2022). It is critical, therefore, to consider whether it is possible to enhance curiosity starting at a young age and to keep children's exploration broad in situations where this might benefit their learning. As developmental trajectories are often most flexible and open to intervention early in development (Gee & Casey, 2015; Wachs et al., 2014), it may be particularly effective to intervene in the early childhood years—when children's exploration begins to show evidence of narrowing (Blanco & Sloutsky, 2024; Gopnik et al., 2017)—rather than waiting until later in life.

Importantly, however, exploring broadly is not always adaptive or feasible. Even young children do not have infinite time and energy and must make strategic decisions about when and how they choose to explore (Blanco & Sloutsky, 2024; Meder et al., 2021; Török et al., 2024). Rather than seeking to universally encourage broader exploration, therefore, it might be more beneficial to focus on enhancing children's sensitivity to cues that indicate when it is helpful to broaden versus narrow their exploration. In the present study, we considered what kinds of verbal messages might encourage children to broaden their exploration in response to uncertainty but also flexibly adapt to other features of the environment, combining the learning potential of broad exploration with the efficiency of strategic exploration. We contrasted these with messages about correctly following rules and instructions, learning from others, and content knowledge (e.g., numerical concepts)—common themes in children's day-to-day pedagogical experiences in both the United States and Turkey (Gol-Guven, 2009; Jirout et al., 2018; Luo et al., 2020; McMullen et al., 2005; Russell, 2011; Thornberg & Oğuz, 2013; Vaisarova & Reynolds, 2022). These kinds of messages have been suggested to dampen children's curiosity (Engel, 2011; Jirout et al., 2018), and while it remains unclear whether they *reduce* curiosity or simply fail to promote its growth, they provide a useful comparison when seeking to understand how we might intervene on childrens' typical experiences to promote strategic exploration.

Studies have shown it is possible to experimentally alter individuals' exploration and curiosity by changing their mindset (Schutte & Malouff, 2023; Sumner, Steyvers, & Sarnecka, 2019). In particular, a recent meta-analysis (Schutte & Malouff, 2023) found that interventions that incorporated an element of *mystery* and stimulated participants' interest in the unknown were the most effective at enhancing curiosity. There is, however, little extant research on the malleability of curiosity and exploration in children; of the 41 studies reviewed in Schutte and Malouff's (2023) meta-analysis, only four included children. Addressing this research gap is both theoretically and practically important. Not only does it have the potential to expand our understanding of mechanisms underlying childhood curiosity and exploration, but it may help illuminate whether it is possible to enhance children's learning by altering how they explore their environment.

In seeking to develop an experimental manipulation that would help us understand how verbal messages can shape children's strategic search for information, we attended to three central factors. First, we drew on extensive work showing that desire to resolve uncertainty is a key element of curiosity and motivator of children's exploration (e.g., Meder et al., 2021; Ruggeri et al., 2023; Stahl & Feigenson, 2015). Second, we followed research suggesting that children's broad and uncertainty-directed patterns of exploration facilitate a more complete and accurate understanding of the search space (Gopnik et al., 2017; Sumner, Li, et al., 2019). Finally, we considered work showing that children make strategic decisions about how they expend time and effort and adapt these decisions flexibly based on experience (e.g., Kidd et al., 2013; Lucca et al., 2020; Ruggeri et al., 2023). Together, these bodies of research informed the three central themes infused in our manipulation: drawing children's attention to uncertainty as a cue to broaden exploration (emphasizing elements of mystery), encouraging children to learn from and adapt to the environment, and highlighting environmental constraints that call for strategic search decisions.

To understand how it might be possible to promote strategic exploration by intervening on children's day-to-day experiences, we contrasted these messages with traditional pedagogical themes that children routinely encounter. These were largely informed by research in educational settings, which occupy much of children's time from a young age (Hofferth, 2009) and are explicitly focused on learning, thus serving as an important vehicle for messages about learning and problem solving. The education systems of both the United States and Turkey are marked by a strong focus on academic preparation and high-stakes testing (Altinyelken, 2013; Russell, 2011). In the United States, this has increasingly shifted down from elementary grades to kindergarten and earlier, leading to greater focus on worksheets, drills, and other activities that emphasize rules and correct answers as opposed to child-directed exploration (Haslip & Gullo, 2018; Russell, 2011). As recently as 2012–2013, U.S. prekindergarten teachers have reported spending at least half of their instructional time—and sometimes much more—engaged in activities planned and structured by the teacher rather than in child-directed, exploratory activities (Vaisarova & Reynolds, 2022). Observational studies mirror these findings, suggesting that U.S. teachers rarely encourage students to generate questions or ideas (i.e., engage in curiosity-driven exploration, Evans et al., 2023; Jirout et al., 2022). Turkish early childhood education settings, too, have been characterized by a strong adherence to rules and structured, teacher-directed activities (Gol-Guven, 2009; Karademir et al., 2020) as well as by pressure to reduce child-directed play to make space for academic activities (Tuğrul et al., 2019). Finally, teachers in both the United States and Turkey tend to ask more closed-ended questions (questions with a single answer) than open-ended questions that encourage children to expand on and explore their ideas (Çalık & Aksu, 2018; Kim, 2015; Köksal, 2022; Lee & Kinzie, 2012). It has been argued that these types of educational practices and the messages they send (about the importance of correct answers and following directions) might fail to promote—or even suppress—children's curiosity (Jirout et al., 2018). We, thus, considered them to be an important comparison against which to test our strategic exploration manipulation intended to influence curiosity.

To test how these different kinds of verbal messages shape children's strategic search for information, we developed two storybooks that embedded contrasting messages about learning, problem solving, and exploration. Shared book reading was chosen as an ecologically valid delivery method, as children's books often embed messages related to learning and problem solving (e.g., achievement orientation, making mistakes; Donaldson et al., 2023; Suprawati et al., 2014) as well as explicitly pedagogical content designed to teach children specific concepts (e.g., numbers, shapes, colors; Luo et al., 2020). The storybook format also allowed us to carefully control how the key messages about learning and problem solving were delivered and ensured that the stories were closely matched except for these key messages.

The *strategic curiosity* story emphasized the importance of uncertainty as a cue for broadening exploration but also encouraged children to strategize their search by responding flexibly to information acquired through exploration and keeping in mind constraints (e.g., time). To further encourage an "exploratory" mindset, children were asked open-ended questions throughout the story that encouraged them to elaborate with their own ideas (e.g., "What should Sam do?"). These kinds of questions have been positively linked to children's engagement in hands-on exploration and thus provided a means of promoting engagement with the story while aligning with its curiosity-promoting messaging (e.g., Willard et al., 2019).

The *control* story, in contrast, was designed to provide an ecologically valid comparison by reflecting the kinds of pedagogical messages and practices often embedded in both United States and Turkish classrooms (Evans et al., 2023; Gol-Guven, 2009; Jirout et al., 2022; Thornberg & Oğuz, 2013) and parent–child joint reading interactions (Durmuşoğlu & Erdem, 2006; Huebner & Meltzoff, 2005; Kotaman, 2007; Ward et al., 2017). In the control story, the main character searched for treasure based on predetermined instructions (e.g., a map and checklist) and did not question or alter their search strategy in response to new information; the emphasis was on correctly following instructions and listening to other characters in order to find the right island. To match the interactive nature of the open-ended questions asked in the strategic curiosity story, children in the control condition were also asked questions. However, in line with the types of questions teachers are likely to ask in the classroom and parents are likely to ask during book reading (Çalık & Aksu, 2018; Huebner & Meltzoff, 2005; Lee & Kinzie, 2012), these were closed-ended and did not invite elaboration (e.g., "How many do you see?"). Finally, to reflect the content knowledge often included in children's books as a pedagogical tool (e.g., concepts of number, shape, etc.; Luo et al., 2020), the control story included content about counting and numerosity.

Exploration Across Countries

As in many domains of psychology, much of the research on children's curiosity and exploration has been conducted in Western, educated, industrialized, rich, and democratic societies, particularly in North America and Western Europe (Henrich et al., 2010). This has limited our understanding of how children explore across cultural contexts and the extent to which mechanisms underlying exploration might be universal. Exploration is a pervasive aspect of human behavior that is observed as early as infancy (Kidd & Hayden, 2015), suggesting it might look similar in children across cultural contexts. However, patterns of exploration have also been shown to relate to contextual factors, such as experiences of scarcity and adversity (Chang et al., 2022; Frankenhuis & Gopnik, 2023; Xu et al., 2023). As such, it is informative to compare exploration across diverse countries to examine the extent to which it might be shaped by culture-specific experiences.

To assess the generalizability of our findings and expand our understanding of mechanisms underlying exploration, we recruited children from both the United States and Turkey. These countries provide an interesting exploratory comparison. Turkey has faced far greater economic difficulties than the United States in recent years (Stoupos et al., 2023), creating uncertain socioeconomic conditions that might shape children's (and their parents') exploration. National economic crises can generate uncertainty and have been linked to increased stress and fear about the future, leading to reduced interpersonal trust and ability to cope with uncertainty (Ananyev & Guriev, 2019; Inklaar & Yang, 2012; Ng et al., 2013). In line with these findings, research has found that adults in the United States tend to report higher levels of interpersonal trust and lower levels of uncertainty avoidance than adults in Turkey (Hofstede, 2011). Turkey has experienced additional economic difficulties since these studies were conducted (i.e., the crash of the Turkish lira in 2018; Hadi et al., 2023), which may further accentuate these differences.

Although children are generally drawn to resolve momentary uncertainty in learning situations, they may adapt to high baseline uncertainty in their environment (e.g., fluctuations in family income) by becoming more uncertainty-averse; this in turn may lead to exploring more narrowly and prioritizing small but certain benefits over riskier and larger ones (Amir et al., 2018; Ellis & Del Giudice, 2019; Michaelson et al., 2013). Indeed, children living in circumstances where uncertainty is higher or its consequences are costlier tend to show more risk-averse and less exploratory behavior (Amir et al., 2020; Xu et al., 2023). Macroeconomic uncertainty might also impact children via socialization processes. Though parents in Turkey value curiosity and autonomy in their children (Ünlütabak et al., 2019), uncertainty avoidance and distrust heightened by economic factors may lead them to model and encourage risk-averse behaviors more than parents in the United States.

Despite multiple reasons why children's experiences in the United States versus Turkey might be expected to produce differences in exploration, it is also possible that we might observe similar patterns of exploratory behavior and similar responses to the exploration-related messages in our storybooks. Similar patterns of exploration would suggest that exploratory behavior—at least as operationalized in our search task—is driven by experiences and cognitive processes that are shared across these two countries. Similar responses to our storybook manipulation would suggest that the specific components embedded in our experimental storybooks play a similar causal role in shaping exploration across these two cultural contexts.

The Present Study

Here, we test whether messages about the value of uncertainty, flexibility, and strategy in exploration shape how children across two countries search for information in a novel virtual environment. These messages were embedded in an interactive book-reading activity, in which the main story protagonist modeled different kinds of search strategies and a researcher encouraged active participation from the child (e.g., via didactic question asking and repetition). This medium is ecologically valid in many cultures, including the United States and Turkey (books are a common didactic tool), and easily scalable for widespread use by caregivers and teachers. While past work has examined how teachers and caregivers can adapt their behavior to shape children's exploration at the moment that children are exploring (e.g., Bonawitz et al., 2011; Willard et al., 2019), such a level of one-on-one adult involvement and responsiveness is not always feasible due to other demands on their time and attention.

Children from the United States and Turkey met with a researcher over Zoom and were randomly assigned to hear either the strategic curiosity or the control story. The strategic curiosity story emphasized embracing uncertainty as a cue to explore, responding flexibly to new information observed in the environment, and keeping in mind practical constraints (e.g., time). The control story mirrored traditional pedagogical themes, such as following rules and directions provided by others in order to arrive at a correct answer (Gol-Guven, 2009; Russell, 2011). The two stories had a parallel storyline, themes, and structure (e.g., illustrations and length) to ensure that they were closely matched in all respects, except the target messages regarding exploration and learning, and were both highly similar to the subsequent virtual exploration task.

We chose to include an "active" control group that heard a story with a similar structure and plot—rather than a control group that did not hear *any* story or heard a story with an entirely different plot—to isolate the effects of our target messages about learning and problem solving and to eliminate potential confounds. If only the strategic curiosity group read a story, subsequent differences in exploration might be due to children's comfort with the experimenter and the testing situation as a function of the reading activity. Alternatively, if the plot of the control story differed substantially from the strategic curiosity story (e.g., did not include themes of search and problem solving), it would be difficult to determine whether effects on children's exploration were driven by the type of story plot (since the subsequent search task itself required search and problem solving) or by the specific approach to search and problem solving conveyed in the stories. Although this active control did not allow us to isolate whether the strategic curiosity condition enhanced strategic exploration or the control story constrained it—relative to children's baseline exploration—this is a critical first step toward understanding whether it is possible to shape strategic exploration by intervening on the pedagogical messages that children tend to encounter in their day-to-day lives.

After hearing their assigned story, children played a virtual game in which they searched for sea creatures across five fish tanks (cf. Hutchinson et al., 2008). Several aspects of the search task made it beneficial for children to be strategic with their search decisions: Some tanks contained many sea creatures while others only contained a few, the amount of time children could spend exploring this virtual environment was restricted (making an exhaustive search impossible), and children were prevented from returning to previous tanks once they had decided to move on. To capitalize on children's curiosity and motivation to learn, they were rewarded for each creature they discovered with both a new piece of information (a fact about the creature) and a corresponding tangible reward (adding the creature to a virtual "collection").

If the strategic curiosity condition leads to more uncertainty-directed exploration and sensitivity to environmental features—relative to the control condition—we anticipated children in this condition would search more flexibly and strategically (e.g., search more persistently in a tank after observing evidence of high-reward density) than children in the control condition and ultimately find more creatures. Additionally, although our search task differed in several ways from foraging and bandit tasks traditionally used to study explore/exploit decisions (e.g., Hutchinson et al., 2008), it posed a similar dilemma—children faced a trade-off between searching the current tank in depth (exploiting their current location) and exploring the possibility of finding more sea creatures in another tank. The two storybooks, too, had related themes—the strategic curiosity story emphasized exploring to gain new information, while the control story emphasized exploiting information that was already known. This might translate into distinct search patterns, with children in the control condition searching more deeply within tanks and children in the strategic curiosity condition searching more broadly across tanks (note that this hypothesis was not preregistered).

Method

Participants

United States

One hundred thirty-eight 3- to 6-year-olds (M_{age} = 4.95 years, SD_{age} = 0.86) were recruited online (e.g., https://ChildrenHelpingScience.com) and participated between December 2020 and June

2022. A further 19 participants were tested but excluded from the analysis due to technological or procedural errors ($n = 6$), refusal to participate ($n = 12$), or developmental delays ($n = 1$). Sixty-nine parents/caregivers reported that their child was female, 68 reported that their child was male, and one reported that their child was nonbinary. Of parents who reported their child's race and ethnicity ($N = 136$), 61.03% described their child as White, 13.24% as Asian/Asian American, 13.24% as Latinx/Hispanic/Latin American, 2.94% as Native American/American Indian/Alaska Native, 1.47% as Black/African American, and 8.09% gave another description. The educational backgrounds of the participants' primary caregivers are summarized in Table 1.

Turkey

Eighty-eight 3- to 6-year-olds ($M_{age} = 5.22$ years, $SD_{age} = 0.76$) were recruited through social media and preschools and participated between April 2021 and September 2022. A further 20 participants were tested but excluded from the analysis due to technological or procedural errors ($n = 1$) or refusal to participate ($n = 19$). Forty-eight parents/caregivers reported that their child was female, and 40 reported that their child was male. Of parents who reported their child's race and ethnicity ($N = 82$), 90.24% described their child as Turkish, 2.44% as Kurdish, 1.22% as Circassian, and 6.10% gave another description. The educational backgrounds of the participants' primary caregivers are summarized in Table 1.

Sample Size Planning

A power analysis correcting for uncertainty using the *Bias- and Uncertainty-Corrected Sample Size* R package (Anderson et al., 2017; Anderson & Kelley, 2020) indicated 132 participants would be sufficient to detect a medium condition effect with 80% power and an α level of .05. We accordingly preregistered a sample of 132 United States children. Although we aimed to test equal samples in both countries, this was not possible because the lead investigator in Turkey moved institutions to another country.

Procedure

This study was approved by the ethics boards at Arizona State University in the United States (STUDY00012799) and at MEF University in Turkey (E-47749665-050.01.04-101). Children were tested over Zoom in English or Turkish, as appropriate. Before beginning the study, researchers obtained informed consent from parents/guardians and verbal assent from children. As compensation, families received a $10 gift card in the United States and a participation certificate in Turkey.

Storybook Manipulation

An experimenter greeted children over Zoom and told them that they would read a story and play a game together. Children were randomly assigned to hear the experimenter read one of two illustrated stories that conveyed different messages about learning and exploration. The stories used identical illustrations showing a character (Scuba Sam) searching for treasure and took approximately 10 min to read. The two stories conveyed different messages about exploration and learning, via both Sam's exploratory behavior and the techniques the experimenter used to keep children engaged.

In the *strategic curiosity* condition, Sam *embraced uncertainty as a cue to explore*—for example, choosing to explore an unfamiliar island rather than one they already knew. Throughout the story, this message was reinforced by encouraging children to repeat the refrain "When we see something new that we didn't know about before, that's our clue to explore!" Sam also *responded flexibly to new information*—for example, by being flexible when an island they found did not perfectly match a description they had heard earlier. Finally, Sam *kept track of constraints on their treasure hunt*, making sure they left enough time to visit all of the islands on their map before it got dark. To keep children engaged and further emphasize the exploratory, information-seeking message of this story, open-ended questions were posed to the child throughout (e.g., "What do you think Sam should do to find out if this is the treasure island?").

In the *control* condition, Sam's behavior reflected more traditional pedagogical themes. Sam carefully *followed rules and instructions*, always checking their map and checklist to see if an island perfectly matched the descriptions given by other characters and fitting the pieces of their checklist together like a puzzle. This message was reinforced by encouraging children to repeat the refrain "If we stick to the map, we'll find clues in a snap!" Rather than relying on their own observations and strategic decisions, Sam *tended to rely on luck*—for example, choosing randomly which island to visit next in their search. To reflect the kinds of pedagogical messages children are likely to see in actual children's books, the story also *embedded common pedagogical content* (e.g., number-related content, asking children to count the turtles they saw). Finally, the engagement questions in this condition were closed-ended (e.g., "Do you see Sam's binoculars?") rather than prompting children to problem-solve and contribute their own ideas.

Illustrative examples of storybook pages that highlight these key elements are shown in Figure 1. Full text of both storybooks (in English and Turkish) can be found on the Open Science Framework

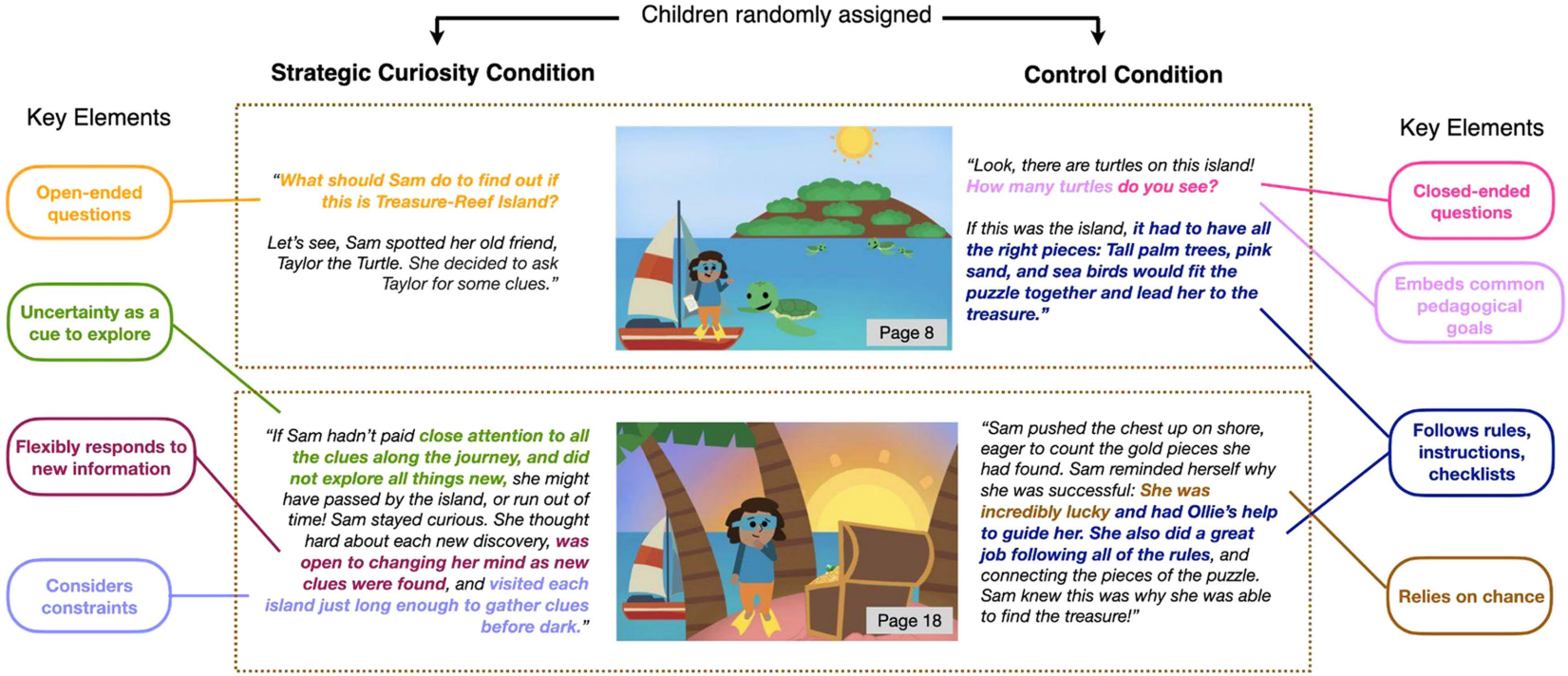
Table 1
Parent/Caregiver Highest Level of Education, by Sample

Education level	% in the United States ($N = 137$)	% in Turkey ($N = 86$)
Less than high school diploma	0.00%	5.81%
High school diploma	3.65%	6.98%
Some college	10.22%	6.98%
4-year college degree	40.88%	45.35%
Graduate degree	45.26%	34.88%

Note. One parent/caregiver in the United States and two in Turkey did not report their education level.

Figure 1

Condensed Excerpts From the Strategic Curiosity and Control Condition Storybooks, Illustrating Key Elements in the Two Conditions



Note. See the online article for the color version of this figure.

at https://osf.io/5sq3c/?view_only=0e96ad8f1f4e40f9a0a298254a3ab3fe.

Story Comprehension. At the conclusion of their assigned story, children were asked three reflection questions and two memory check questions to assess story comprehension. For details, please refer to the Supplemental Materials.

Translation and Adaptation. Both stories were initially written in English and translated into Turkish by the Turkish research team. Four members of the Turkish team collaboratively translated the story and came to an agreement on translations. Priority was given to ensuring the language used would be natural and familiar to children, rather than maintaining a rigid word-for-word translation, while also ensuring all the key elements of the experimental manipulation were incorporated. In consultation with the U.S. team, several adaptations were made to ensure the story and translation were appropriate for the Turkish context. For instance, rather than matching gender pronouns for "Scuba Sam" to each participant (as in the English version of the stories), a common gender-neutral name was selected for the Turkish version. For other characters, the team selected Turkish names that better fit the cultural context.

Story Validation. To ensure the two storybooks were equally engaging and conveyed their target message, we validated them with a U.S. adult sample prior to collecting data with children. Adult participants ($N = 34$) read both stories in a counterbalanced order and rated their engagement level on a 10-point Likert scale. Participants rated the strategic curiosity story ($M = 7.59$, $SD = 2.23$) and control story ($M = 7.38$, $SD = 2.46$) as equally engaging, $t(33) = 0.54$, $p = .596$. To summarize the main intervention elements in each story, we asked participants to classify each story as having either a "mystery" or "puzzle" theme. Participants were given the following definitions, with the mystery definition reflecting themes of the strategic curiosity story and the puzzle definition reflecting themes of the control story:

1. "to solve a mystery, you need to explore all the possible answers"
2. "to solve a puzzle, you need to carefully follow the directions and put the pieces together in exactly the right way"

Most participants (97%) correctly identified that the strategic curiosity story conveyed a mystery message, and 100% identified that the control story conveyed a puzzle message.

Search Game

Following the story, children were told they would play a game and were asked to play "just like Sam" by either "staying curious and paying careful attention to everything around you" (strategic curiosity condition) or "following the rules and checking for all of your clues" (control condition). The first experimenter then left the call, before a second experimenter (naive to condition) joined and told children they would visit a virtual aquarium containing five fish tanks, with different sea creatures hiding in each tank. Children were told they would only have 15 min to look at sea creatures because the aquarium was closing soon.

The remainder of the search game was identical across conditions. Each of the five tanks contained eight hiding spots, marked by different colored circles. For each search attempt, children decided whether to stay in the current tank and check another spot or move on to explore a new tank, with the caveat that once they left a tank, they could not return to it. Three tanks (Tanks 1, 4, and 5) were high in rewards (75% of hiding spots contained a creature), and two tanks (Tanks 2 and 3) were low in rewards (25% of spots contained a creature). The reward sequence (order of tanks and rewards or misses in each tank) was fixed across children (see Supplemental Figure S1). To simulate real-world search, there was a "travel cost" (a short transition video) associated with each search attempt—searches within tanks were shorter (12 s) than transitions across tanks (24 s).

The search game structure is illustrated in Figure 2. Before beginning the game, children reviewed the rules, practiced searching in a demonstration tank, and completed a four-question comprehension check (see Supplemental Materials for details regarding these aspects of the procedure). The game ended either after 15 min had passed, when the child asked to stop, or when they had completed the game by reaching the final tank and searching all eight hiding spots. Although most children (75.22%) explored for the full time, 24.78% ($n = 56$) ended early—either because they completed the game before time was up ($n = 29$, 12.8% of the sample) or because they chose to stop the game early ($n = 27$, 11.9% of the sample). Of the 27 children who decided to end early, most ended the game after reaching the final tank; only three did so before this point. There was no evidence that children's probability of choosing to end the game early differed by condition or country ($ps > .90$; see Supplemental Materials for details).

Measures of Search Behavior. The search game was designed to capture the effectiveness of children's search strategies (number of creatures or rewards found), search effort (how many times they chose to search in each tank[1]), persistence (how many times they continued searching in a tank despite not finding rewards), ability to strategically search their environment (detect when a tank is low vs. high in rewards and modify behavior accordingly), and tendency to search individual tanks in depth versus broadly exploring many tanks (number of tanks explored[2]). We also measured time-based versions of these variables (e.g., time searching each tank, in addition to number of spots searched). Search behavior variables are described in Table 2 (Supplemental Table S3 shows observed ranges for each tank).

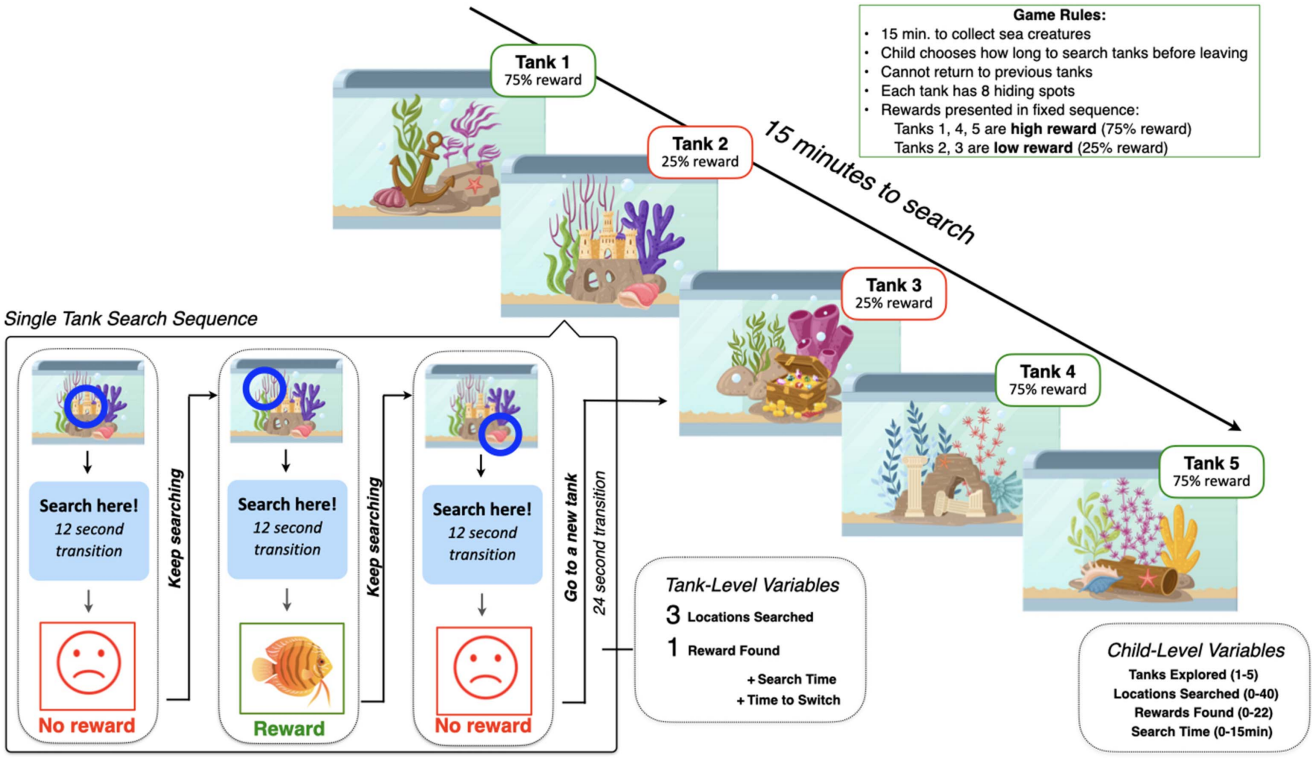
Children's search decisions were coded live during the Zoom call. Additional coding of behavior was done offline from the session's recorded video. An independent observer coded a random 20%–50% of sessions offline to establish very high interrater reliability (values ranged from .80 to 1.0, median .99; see Supplemental Table S4).

Task Engagement. Children's engagement was rated separately during the storybook and search game phases (see Supplemental Materials for details and descriptive statistics). Based on the strong correlation between these scores (Spearman's $r = .57$, $p < .001$), they were averaged to create an overall "task engagement" index.

[1] Number of unsuccessful search attempts in each tank (searches that did not yield a reward) was also coded but not analyzed. A strong correlation with total search attempts in each tank ($r_S = .75$) suggested that these variables did not capture distinct aspects of behavior.

[2] Number of tanks visited (tanks the child visited even if they did not search there) was also coded. However, due to the strong correlation with tanks explored ($r_S = .74$) and because the number of tanks explored theoretically better reflected search for information, only tanks explored was considered in primary analyses.

Figure 2
Illustration of Search Game Procedure



Note. An example search sequence is shown in the bottom left, where a child searched in three of eight possible hiding spots in the second tank environment. Images by Vasilchuck/Adobe Stock and by WinWin/Adobe Stock. Note that the imagery (e.g., tanks, fish, backdrops) used in the experiment was slightly different from what is shown here; it is modified for copyright purposes. See the online article for the color version of this figure.

Additional Tasks

Following the search game, children watched a video of an animated character playing the same game and completed a shared storybook reading task with their caregiver (these data are reported elsewhere and are not discussed in the current article).

Executive Function. Children completed a virtual version of the dimensional change card sort to assess executive function (EF) skills (Zelazo, 2006). This was included as an exploratory measure, given that executive functions might play a role in the ability to track and respond flexibly to environmental features (e.g., reward density of specific tanks). In our sample, this task had substantial missing

Table 2
Search Behavior Measures, Including Ranges of Possible Values

Variable	Description	Possible range
Child-level variables (computed for each child)		
Rewards found	Total number of rewards found during the game	0–22 rewards
Tanks explored	Total number of tanks in which the child searched at least one hiding spot	0–5 tanks
Tank-level variables (computed for each tank)		
Locations searched	Number of hiding spots the child searched in the tank	0–8 locations
Search time	Time spent searching in the tank (in seconds)	0–900 s
Time to switch[a]	Consecutive time (in seconds) spent searching unsuccessfully right before switching to a new tank, that is, time between last reward found (or start of search in the tank, if no rewards found) and decision to switch	0–900 s

[a] Only coded when children switched voluntarily (not because they ran out of spots to search). A count-based version of this variable (number of unsuccessful searches before switching) was also coded but not analyzed as a primary outcome due to (a) limited variability, which resulted in singular model fit (maximum number of consecutive misses was 4; 99.2% of actual values were between 0 and 2), and (b) this variable, unlike the time-based variable, did not account for repeated searches in the same location. These time- and count-based variables were highly correlated in both low-reward (r = .79) and high-reward (r = .83) tanks, suggesting time to switch reflects children's active search effort.

data (10.2% of children) and limited variability (71.9% of children who completed the task passed; see Supplemental Materials for further details). Given these limitations, we compared children's likelihood of passing the EF task across storybook conditions to help verify the effectiveness of random assignment, but we did not have sufficient variability to examine EF as an individual differences measure in exploratory analyses.

Transparency and Openness

This study was preregistered in August 2021 on the Open Science Framework, and the preregistration and analytic plan can be found at https://osf.io/48x6f. De-identified data, R analysis script, and study materials can be found on the project Open Science Framework page (Kiefer et al., 2024) available at https://osf.io/5sq3c/?view_only=0e96ad8f1f4e40f9a0a298254a3ab3fe.

In the preregistered analytical plan, we proposed to test main effects of the storybook manipulation on search behavior using independent-groups *t* tests. This approach, however, would not allow us to control for other variables, to probe interactions (between storybook condition and reward frequency and between country and storybook condition), or to examine how children's search unfolded across multiple tanks. We therefore determined that regression was a more appropriate analytical tool, and the analyses reported below deviate accordingly from the preregistered approach. For completeness, we report the results of our preregistered *t*-test analyses in the Supplemental Materials; these results were broadly consistent with the findings reported here.

Results

To understand the effect of the storybook manipulation on children's exploration, we examined three aspects of search. First, we examined overall search performance, operationalized as the number of rewards found. Second, we examined whether children adjusted behavior based on reward frequency by comparing their behavior in low- and high-reward tanks. Finally, in a set of exploratory analyses, we examined search across tanks to probe how children balanced exploring the current tank in depth versus moving on to explore new ones. To test whether children's search varied across countries, a main effect of country was included in models that examined the main effect of storybook condition (though not in more complex models, where main effects were not readily interpretable). Interactions between country and storybook condition were omitted from primary models, because we did not hypothesize *a priori* that the effects of the story manipulation would vary by country. However, given the possibility that an uncertainty-based story could have different impacts on children experiencing different levels of macroeconomic uncertainty, we followed up primary analyses by fitting models with a Country × Storybook interaction. We also did not expect age differences in the effect of storybook condition, but given the wide age range, we followed up primary analyses by fitting models with an Age × Storybook interaction. For all models, we also examined residuals to identify potential outliers; for brevity, this is only mentioned if excluding these points eliminated the target effect.

Preliminary Analyses

To verify that random assignment created similar experimental groups, we compared age, task comprehension, task engagement, and executive function across conditions using independent samples *t* tests (age), Wilcoxon signed-rank tests (comprehension and engagement), or chi-squared tests of independence (executive function). Children were similar on all variables except story comprehension, which was significantly higher in the control condition (see Supplemental Table S6 for descriptives). Because the two conditions involved different stories, this difference was likely a product of the stories rather than child characteristics, and we concluded that random assignment successfully created comparable groups. We also compared the same child characteristics across countries and found the U.S. sample was significantly younger, scored higher on game comprehension, and was rated higher on task engagement (see Supplemental Table S7 for descriptives). To help ensure that these differences did not confound our findings, we included age, story comprehension, game comprehension, and task engagements as covariates whenever they showed significant bivariate correlations with the outcome variable.

Overall Search Performance: Rewards Found

To examine the effect of the story manipulation on overall search performance, we fit a linear model regressing total rewards found on storybook condition and country, controlling for age, engagement, game comprehension, and number of tanks explored. Storybook condition did not uniquely predict rewards found ($B = -0.06$, 95% CI [−0.50, 0.37], $p = .776$), and older children found significantly more rewards than younger children ($B = 0.04$, 95% CI [0.02, 0.07], $p < .001$). Full model results are available in the Supplemental Table S8. Follow-up analyses suggested the effect of storybook condition did not vary significantly by country or age (see Supplemental Table S8).

Strategic Adjustment to Reward Frequency

To examine the effect of the story manipulation on adjustment to low- versus high-reward environments, we focused on two aspects of search within tanks: search effort (indexed by number of locations searched and search time) and persistence (indexed by time searching unsuccessfully immediately before switching to a new tank). To capture children's response to information generated by their own search, analysis was limited to tanks explored; tanks children chose to skip or did not have time to explore were coded as missing. Each child's behavior in each tank was treated as a data point, and the *lme4* R package (Bates et al., 2015) was used to fit a mixed-effects model with main effects of storybook condition and reward density, an interaction between storybook condition and reward density, and a participant random effect for the intercept. Search effort variables were modeled using linear models, and time to switch was modeled using a generalized linear model with a gamma distribution. Models predicting search effort variables also controlled for age, engagement, and comprehension.

Search Effort

Model estimates indicated that children searched significantly more locations and spent more time searching in high- versus low-reward tanks (Table 3; Figure 3A). However, this effect did not vary by storybook condition.

Table 3

Coefficient Estimates for Linear Mixed-Effects Models Predicting Search Behavior Across Low- Versus High-Reward Environments

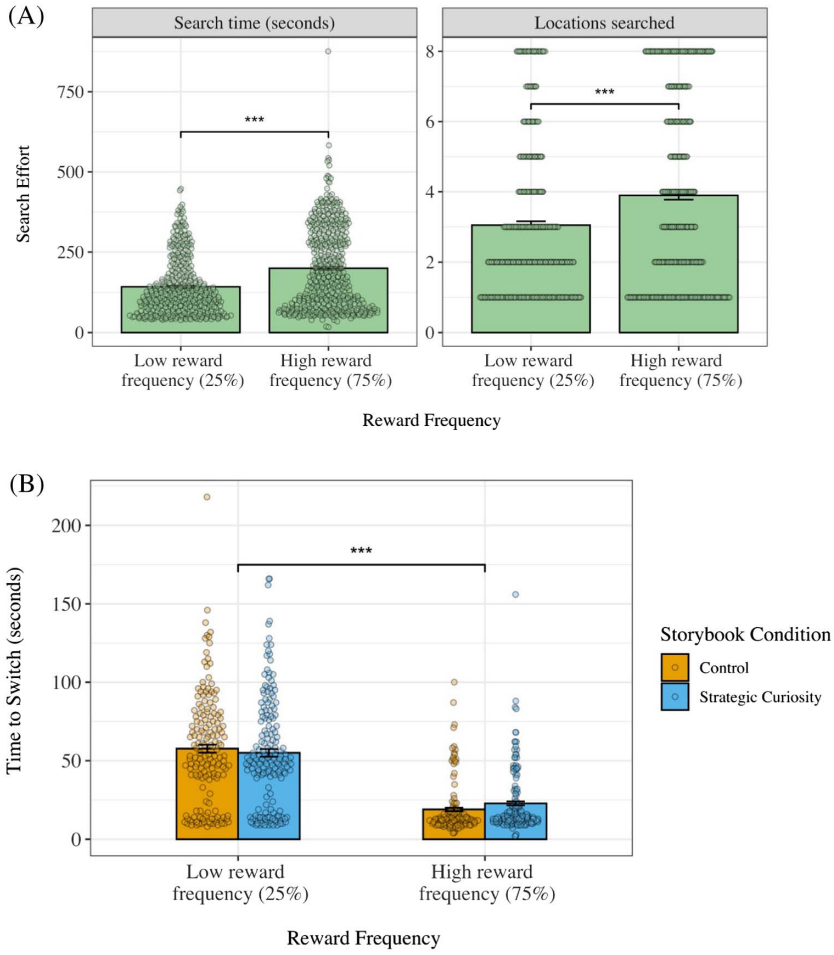
Predictor	Outcome: Location searched/tank		Outcome: Search time/tank		Outcome: Time to switch	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Age (months)	0.02†	[0.00, 0.04]	0.15	[−0.78, 1.14]		
Engagement	0.002	[−0.01, 0.02]	−0.44	[−0.99, 0.22]		
Story comprehension	0.63	[−0.45, 1.78]	54.06*	[6.99, 101.89]		
Game comprehension	0.12	[−0.73, 1.02]	−1.50	[−46.28, 37.22]		
Strategic curiosity story	−0.31	[−0.85, 0.20]	−11.99	[−33.31, 11.69]	−0.07	[−0.25, 0.11]
Reward frequency: High	1.00***	[0.57, 1.42]	62.69***	[41.61, 80.56]	−1.14***	[−1.29, −1.00]
Storybook × High Reward	0.03	[−0.59, 0.67]	1.50	[−24.46, 28.99]	0.23**	[0.03, 0.42]

Note. Models also include an intercept and corresponding participant random effect (not shown). CI = confidence interval.
$^{\dagger}p < .1$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Moderation by Country and Age. To test whether the effect of the story manipulation on response to reward frequency differed by country or age, we fitted two additional sets of models: one that added all two-way interactions between storybook condition, reward frequency, and country or age to the models in Table 3 and one that further added a three-way interaction between these variables. We compared the fit of these models using likelihood ratio tests (LRTs). The effect of storybook condition on adjustment to low- versus high-

Figure 3

Distribution of (A) Search Effort and (B) Unsuccessful Search Time Immediately Preceding a Decision to Switch Tanks, Across Low- and High-Reward Tanks



Note. Error bars denote ± 1 standard error. See the online article for the color version of this figure.
$^{***}p < .001$.

reward environments did not differ by country for locations searched ($B = -0.40$, 95% CI [−1.79, 1.02], $p = .538$) or search time ($B = -26.18$, 95% CI [−91.99, 30.39], $p = .385$). It also did not differ by age for locations searched ($B = 0.03$, 95% CI [−0.04, 0.10], $p = .335$) or search time ($B = 1.64$, 95% CI [−1.27, 5.00], $p = .271$).

Persistence

Model estimates suggested that children took longer to switch out of low-reward than high-reward tanks when their search was unsuccessful (Table 3). However, this effect was qualified by a significant interaction with storybook condition ($B = 0.23$, 95% CI [0.03, 0.42], $p = .024$), indicating that the effect of storybook condition was different in low- versus high-reward tanks. We examined the effect of storybook condition separately in each reward environment, applying a Benjamini–Hochberg *p*-value adjustment using the *emmeans* package in R (Lenth, 2023). These simple effects were not significantly different from zero, but the mean pattern was in opposite directions (Figure 3B). In high-reward tanks where staying was more likely to yield rewards, children in the strategic curiosity condition showed *greater* persistence than children in the control condition ($B = 0.15$, $p = .225$). Conversely, in low-reward tanks where staying was less likely to yield rewards, children in the strategic curiosity condition showed *less* persistence than children in the control condition ($B = -0.07$, $p = .429$). In sum, the strategic curiosity condition was associated with more adaptive adjustment.

To help bolster the interpretation that this pattern was driven by children's observations of reward frequency, we ran a second set of analyses using children's own observed reward frequency (proportion of search attempts that yielded a reward) in place of the designed 25%/75% reward frequency manipulation. For example, if a child searched once in Tank 2 (a low-reward tank), their observed reward frequency would be 0%; if a child searched three times in Tank 2, their observed reward frequency would be 33% (see Supplemental Figure S1). Similar to the main analyses, the effect of storybook condition differed based on observed reward frequency ($B = 0.29$, 95% CI = [0.08, 0.49], $p = .006$), with children in the strategic curiosity condition tending to persist longer than children in the control condition as observed reward frequency increased and the pattern reversing as observed reward frequency decreased (see Supplemental Figure S2).

Moderation by Country and Age. To test whether the effect of the story manipulation on response to reward frequency differed by country or age, we fitted two additional sets of models: one that added all two-way interactions between storybook condition, reward frequency, and country or age to the models in Table 2 and one that further added a three-way interaction between these variables. We then compared the fit of these models using LRTs. The effect of storybook condition on adjustment of persistence (time to switch) to low- versus high-reward environments did not differ significantly by age ($B = 0.01$, $p = .270$) or by country ($B = -0.41$, $p = .058$). To maintain consistency with our preregistration and avoid drawing conclusions based on what may not be a replicable effect, we interpret this latter finding as a null effect. However, it is important to note that this *p* value is very close to conventional levels of statistical significance, and we encourage future research to replicate these results before drawing a definitive conclusion regarding cross-cultural differences in the effect of our story manipulation on patterns of persistence.

Exploration Depth Versus Breadth

To understand how children navigated decisions about searching a tank in-depth versus moving on to explore others, we examined how search unfolded throughout the game. First, we examined allocation of search effort across all tanks using longitudinal models. Second, because children's choices in the first tank influenced opportunities for later exploration, we analyzed behavior in this specific tank. Finally, to examine exploration breadth, we tested the effect of storybook condition on the total number of tanks explored.

Behavior Across Tanks

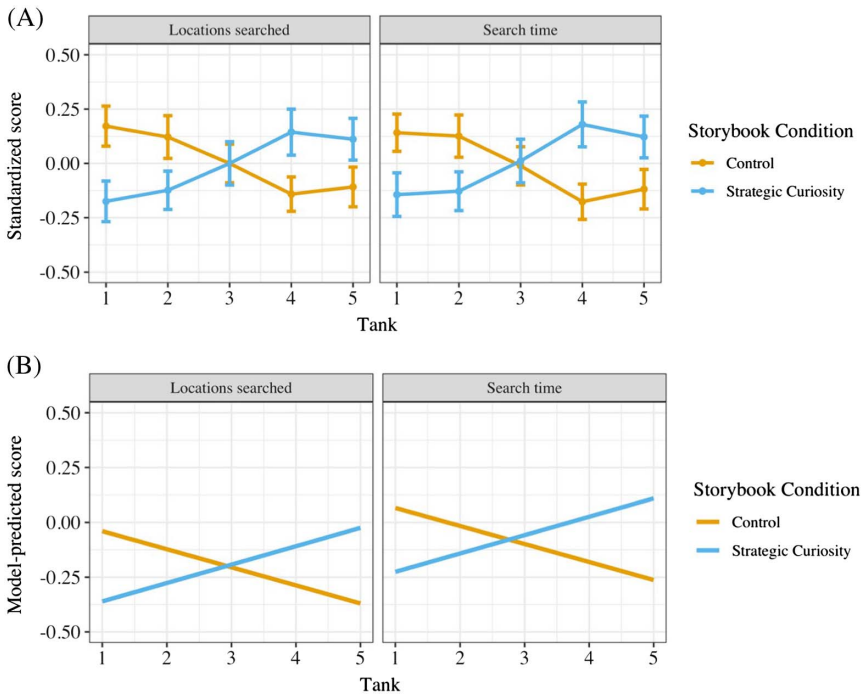
Our search task forced a trade-off between deeply searching one tank and broadly exploring multiple tanks; The more children searched in earlier tanks the less time was available for exploring later ones. To characterize how children navigated this trade-off, we examined allocation of search effort (search time and locations searched) across all five tanks. To account for differences due to reward frequency, data were standardized within tanks (e.g., a value of 1 indicates 1 *SD* above the sample mean for that tank). To fully capture children's trade-offs, tanks they skipped or did not have time to explore were assigned values of 0.

Because change in search effort across tanks appeared approximately linear for many participants (Supplemental Figure S3), we modeled it as a linear function of tank number. These mixed-effects models included random effects of intercept and slope and controlled for age, comprehension, and engagement. To examine whether the story manipulation predicted trajectories of search effort, we added storybook condition to the Level 2 models for intercept and slope and used LRTs to assess improvement in model fit due to the resulting Storybook × Tank interaction. This interaction significantly improved fit for both locations searched ($B = 0.17$, 95% CI [0.04, 0.28], $p = .009$) and search time ($B = 0.17$, 95% CI [0.04, 0.28], $p = .010$), indicating storybook condition explained significant variance in slopes (change in search effort across tanks). Both models suggested children in the strategic curiosity condition tended to devote relatively less search effort to earlier tanks and more to later ones ($B = 0.084$, $p = .054$ for locations; $B = 0.083$, $p = .063$ for time), while children in the control condition showed an opposite trend ($B = -0.082$, $p = .075$ for locations; $B = -0.083$, $p = .071$ for time; see Figure 4 for raw means and model predictions).

Developmental Differences. Given the developmental changes in exploratory behavior that have been documented across our participant age range (Blanco & Sloutsky, 2024; Pelz & Kidd, 2020), we explored whether patterns of search effort in our task also varied by age. To do so, we fitted longitudinal models predicting search effort (time and locations) as a linear function of tank number; models included random effects of intercept and slope and controlled for task comprehension and engagement. Age was added to the Level 2 models for intercept and slope, and LRTs were used to assess improvement in model fit due to the resulting Age × Tank interaction. There were significant interactions between Age and Tank: Age explained significant variance in slope (change in search effort) across tanks for both locations searched ($B = -0.008$, 95% CI [−0.01, −0.005], $p < .001$) and search time ($B = -0.007$, 95% CI [−0.01,

Figure 4

Change in Search Effort Across Tanks



Note. Values are standardized within tank, with zero representing the tank-level mean (e.g., 0.25 = 0.25 *SD*s above the tank mean). Panel A shows raw means and standard errors. Panel B shows fixed-effect estimates from longitudinal models with age, comprehension, and engagement held constant. See the online article for the color version of this figure.

0.00], $p < .001$). Both models showed that older children devoted more search effort to earlier versus later tanks, while younger children showed the opposite pattern (Figure 5).

As age and the strategic curiosity storybook manipulation seemed to have similar effects on how children navigated our search task, we further examined how these factors operated in tandem. In an exploratory analysis, we added a three-way interaction between storybook condition, age, and tank number (and all constituent two-way interactions) to the longitudinal model described above. While the three-way interaction did not significantly improve model fit for either locations searched ($p = .270$) or search time ($p = .204$), conditional means suggested that the effect of storybook condition was more pronounced for younger children (see Figure 5).

First Tank

Behavior in the first tank influenced later search opportunities and reflected the most proximal effect of the storybook manipulation. To examine the effect of storybook condition in this tank, we fitted linear models regressing search time and locations searched on storybook condition and country and controlling for age, engagement, and comprehension. Children in the strategic curiosity condition searched significantly fewer locations ($M = 3.84$, $SD = 2.74$) than children in the control condition ($M = 4.80$, $SD = 2.72$; $B = -0.78$, 95% CI [−1.47, −0.09], $p = .026$), although they did not spend significantly less time searching the tank ($p = .083$; see Supplemental Table S10). The effect of the story manipulation did not vary by country or age for either measure of search effort (locations searched or search time; see Supplemental Tables S9–S10).

Exploration Breadth

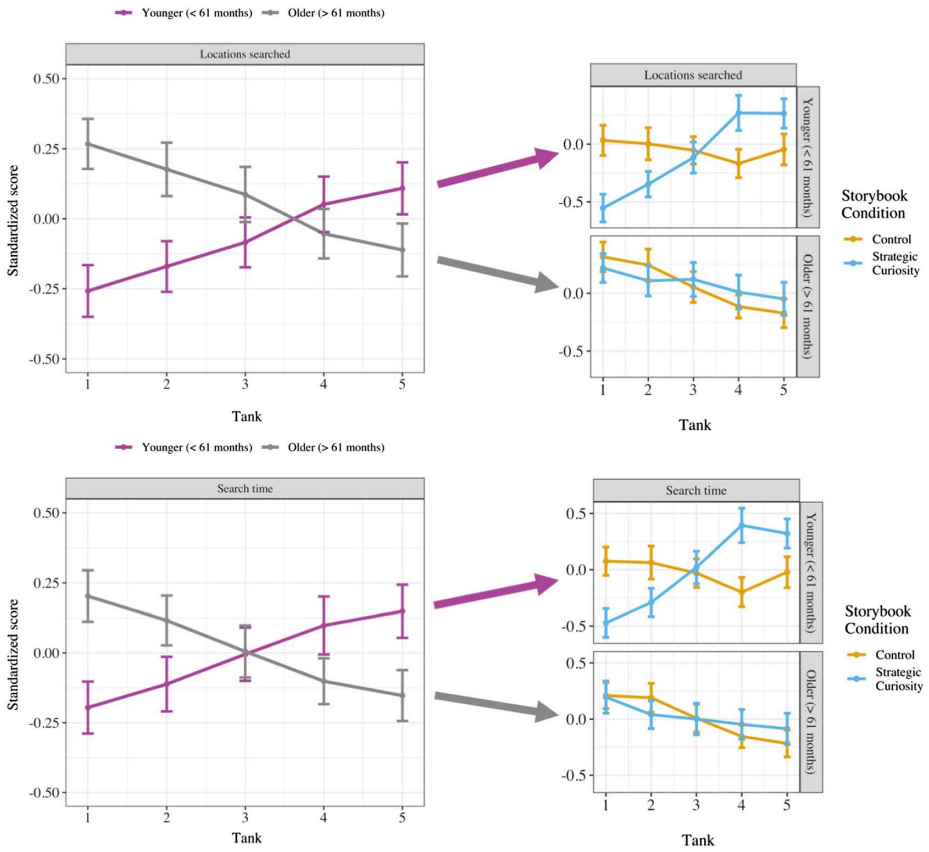
Finally, we probed exploration decisions by examining the number of tanks explored. Because the distribution was skewed (49.56% of children explored all tanks), we coded whether or not children explored all five tanks and fit a logistic model regressing this dichotomous outcome on storybook condition and country (controlling for age and engagement). Children in the strategic curiosity condition were significantly more likely to explore all five tanks than children in the control condition (56.25% vs. 42.98%, respectively; $B = 0.61$, 95% CI [0.07, 1.16], $p = .028$). Children in Turkey were also significantly less likely to explore all tanks than children in the United States (36.36% vs. 57.97%, respectively; $B = -0.72$, 95% CI [−1.37, −0.08], $p = .028$; Figure 6; see Supplemental Table S11 for full model results). The effect of the storybook manipulation did not vary by country or age (see Supplemental Table S11).

Discussion

The present study examined the malleability of 3- to 6-year-old children's curiosity-driven exploration, testing whether their strategic exploration of a novel virtual environment could be influenced by messages embedded in a storybook. Children from the United

Figure 5

The Effect of Age on Children's Search Behavior Across Tanks, With Age Median Split for Plotting (Mdn = 61 Months)



Note. Error bars represent ± 1 *SE*. *SE* = standard error. See the online article for the color version of this figure.

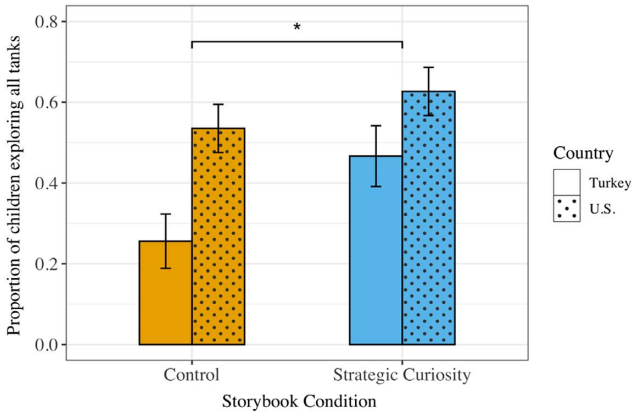
States and Turkey were randomly assigned to hear either a strategic curiosity story (which encouraged uncertainty-directed exploration and adapting flexibly to new information while keeping in mind task constraints) or a control story that contained more traditional pedagogical themes (e.g., carefully following instructions). The stories children heard led to different patterns of exploration across fish tanks in a virtual aquarium. Children in the strategic curiosity condition expended less time and effort searching earlier tanks and were more likely to explore all tanks, prioritizing the opportunity to visit multiple tanks over deeply exploring individual ones. In contrast, children in the control condition tended to explore earlier tanks more deeply; as a result, they often ran out of time to explore all five tanks. These differences in search did not translate to differences in overall rewards found, likely because the first and last tanks both contained a large number of rewards, and children using both approaches had ample opportunity to find rewards.

The story manipulation also shaped how flexibly children adjusted their exploration based on the observed probability of finding rewards. Children in both storybook conditions spent less time searching in low-reward than high-reward tanks, showing some sensitivity to the differing probability of finding creatures. However, there was also evidence that the messages embedded in the stories affected the flexibility of children's search. Children in the strategic curiosity condition showed more strategic persistence in the face of difficulty than children in the control condition, persisting more when they had evidence that this would pay off. Specifically, in the strategic curiosity condition, children showed greater tolerance for longer periods of failure (i.e., searching without finding a reward) in high-reward tanks where persistence was likely to result in a payoff. However, they persisted slightly less in low-reward tanks where the probability of payoff was lower. Collectively, the results suggest that the messages embedded in our stories impacted strategic exploration; children in the strategic curiosity story explored the search space more broadly, rather than narrowly and deeply, and adapted their search strategies more flexibly in response to reward probabilities, though these effects were less robust.

Older children in this study tended to display a search pattern that prioritized depth over breadth, similar to the pattern shown overall by children in the control condition. They expended more effort than younger children on searching earlier tanks—searching them more thoroughly—which left less time to search later tanks. Younger children, in contrast, tended to expend less effort in the earlier tanks and were left with more time to search later ones. This developmental pattern aligns with past research showing a developmental shift from

Figure 6

Proportion of Children Who Explored All Five Tanks, by Storybook Condition and Country



Note. Error bars represent ± 1 standard error. See the online article for the color version of this figure.
* $p < .05$.

broad exploration of new options to narrower exploitation of known options (e.g., Liquin & Gopnik, 2022; Şen et al., 2024). Our search task, therefore, appears to tap into similar processes as tasks commonly used to study the explore–exploit trade-off (e.g., bandit tasks and patch foraging tasks). Although there were some indications that younger children's allocation of search effort might have been slightly more affected by the story they heard, these effects were not statistically significant and would require further investigation with larger samples. Future developmental work in this area would also benefit from fine-grained measures of metacognitive and executive processes, to better understand how and why children at different ages change their strategic search behaviors in response to messages in storybooks. Although the present study included a measure of executive function, the limited variability and substantial missing data in this measure precluded an informative analysis of how executive abilities might be involved in the observed storybook effects and developmental changes.

The effects of the story manipulation on search patterns were similar across the United States and Turkey, suggesting that these effects generalize to children in different cultural contexts. Overall patterns of exploration were also similar across countries, with one notable difference. Children in Turkey were significantly less likely than children in the United States to explore all five tanks, possibly because they spent more time on each individual search attempt (see Supplemental Materials). While our findings cannot pinpoint the precise mechanisms behind this difference, it is possible that cultural differences in socialization regarding novelty and uncertainty or in comfort with our study design (e.g., interacting with a stranger via video call) played a role.

Theoretical and Practical Implications

Our findings suggest that messages about learning and problem solving embedded in storybooks can influence children's exploration of a problem space. From the comparison of our two storybook conditions, we cannot definitively conclude whether the strategic curiosity story *enhanced* children's strategic exploration relative to their typical exploratory behavior, whether the control story *reduced* strategic exploration, or whether there was some combination of these two effects. Further research comparing children's exploration following a strategic curiosity story to their baseline exploration without any manipulation is needed to clarify whether the curiosity-enhancing themes in this story actually enhanced exploration. However, we believe the comparison in the present study still has important implications for educators and parents aiming to encourage children's curiosity and exploration. Our results suggest that attending to pedagogical messages embedded in children's day-to-day experiences and replacing some messages reminiscent of our control story (e.g., rule following, closed-ended questions) with messages more reminiscent of the strategic curiosity story (e.g., approaching uncertainty, adapting flexibly to new knowledge) could have a positive impact on exploration.

Identifying ways to broaden children's exploration is critical given that breadth and flexibility of exploration begin to decline as early as ages 4 to 6 in favor of narrower thinking focused on applying existing heuristics and knowledge (Gopnik et al., 2017). This latter way of thinking can restrict the ability to generate counterintuitive solutions to problems (Gopnik et al., 2017), make individuals vulnerable to learning traps (Blanco et al., 2023; Liquin & Gopnik, 2022), and limit the ability to detect new changes in an environment (Sumner, Li, et al., 2019). Accordingly, curiosity-promoting interventions could be especially useful when introducing children to a counterintuitive concept where applying previous heuristics might be misleading (e.g., when learning certain scientific concepts, such as natural selection; Kelemen, 2019).

Relative to the control story, hearing the strategic curiosity story also appeared to result in children adjusting their exploration more strategically based on the observed probability of finding rewards in each tank. This pattern suggests the story helped draw children's attention to cues indicating when it would be helpful to persist in searching a particular tank (because there were more creatures to find and more to learn) and when there was more to learn from moving on. In other words, it helped them be sensitive and respond flexibly to environmental features. This effect did not produce a difference in the overall number of creatures or rewards found—possibly because children's preference to explore tanks deeply versus broadly was a more dominant influence on their search behavior, and both of these approaches led to thoroughly searching at least one high-reward tank (Tank 1 or Tank 5). However, it contributes to a growing body of work aiming to identify ways to train "adaptive" persistence—making strategic decisions about the utility of persisting in the face of challenge (Leonard et al., 2023; Lucca et al., 2020)—by suggesting a curiosity-promoting story might encourage children to explore not just more broadly but also more strategically. As with our other findings, further research is needed to clarify whether the strategic curiosity story enhanced children's adaptive persistence or the control story reduced it relative to baseline levels.

Limitations and Future Directions

The present study found that a storybook manipulation influenced the breadth and, to a lesser extent, flexibility of young children's exploration. The strategic curiosity story incorporated multiple research-based elements designed to enhance exploration: uncertainty as a cue to explore, encouragement to flexibly adapt and learn

from the environment, and attention to environmental constraints that call for strategic search decisions. This was accomplished through multiple strategies in the story, such as prompting children with open-ended questions and encouraging them to take a mystery-oriented approach to problem solving. Results indicate that these elements resulted in a different pattern of exploration, compared to a story that emphasized following rules and relying on others' directions rather than one's own strategy (as is common in traditional childhood learning contexts; e.g., Gol-Guven, 2009; Russell, 2011). However, further research is needed to parse whether this effect was due to increased exploration in the strategic curiosity condition or decreased exploration in the control condition and whether it was driven by a specific story element or by a combination of these elements. It is also possible that different elements of the stories shaped different aspects of exploration. For instance, perhaps the emphasis on uncertainty as a cue to explore motivated children to prioritize exploring all five tanks (leaving none of them "unknown"), while the emphasis on adapting to new information encouraged strategic adaptation based on reward frequency.

While the present study speaks to the immediate effects of a storybook manipulation on children's curiosity-driven exploration, it remains to be seen how long these effects last and how broadly they generalize to other exploratory settings. In the present study, children's exploration was examined immediately following the story in the context of a search task that had parallel features to the story plot (e.g., multiple locations to visit, a time limit). To better understand the implications of this work for children's long-term curiosity, it will be important to examine whether similar effects can be observed over longer stretches of time, in diverse exploratory settings, and without explicit instructions to apply the exploratory mindset conveyed in the experimental story to a new situation.

Finally, the present study took an important step toward understanding exploration and the factors that shape it across countries. The findings indicated few differences in how children in the United States versus Turkey explored a new virtual space and how these patterns of exploration were shaped by a storybook manipulation. This suggests similar processes are involved in exploration across these countries and their sociocultural contexts. Notably, however, this element of the study was exploratory, and the design was unable to directly tap into causal pathways whereby macrolevel sociocultural differences—including economic conditions—might shape exploration. Specifically, we did not measure individual differences in proximal sociocultural factors (e.g., parental attitudes and socialization) that might mediate macrolevel influences on children's exploration.

Constraints on Generality

To assess the generalizability of our findings across multiple sociocultural contexts, we recruited children from two countries—one with relatively higher macroeconomic stability (the United States) and one with lower macroeconomic stability (Turkey). Importantly, caregivers in both of our samples tended to be highly educated, which may have at least partly buffered children from the economic fluctuations—and resulting uncertainty and adversity—that can shape exploration (Frankenhuis & Gopnik, 2023; Lloyd et al., 2022). While the same level of education in the United States versus Turkey may not correspond to comparable economic security—especially given the recent high rates of inflation impacting all Turkish residents (Hadi et al., 2023)—it is possible that by comparing highly educated families from both countries, we did not fully capture the effects of national macroeconomic uncertainty on children's exploratory behaviors. To understand how sociocultural contexts shape exploration, future research should aim to recruit more socioeconomically diverse samples, from countries beyond the two examined here, and directly measure economic and social factors (e.g., food and housing insecurity, parental socialization) that might mediate between macrolevel contexts and developmental outcomes.

Conclusion

In a changing world full of unpredictable problems, it is important to discover how to help children flexibly and strategically explore new possibilities. Our findings suggest that caregivers and educators can encourage children to explore new situations more broadly and strategically by encouraging them to adapt flexibly to the environment and embrace uncertainty as a cue to explore, rather than rigidly following what is already known. This shift in the verbal messages children hear could have important implications for their learning and problem solving, stimulating their curiosity and leading them to better adapt to new and unpredictable challenges.

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