Early experiences shape children's explore-exploit decisions: evidence from the rural-urban gap

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Abstract

Explore-exploit decisions begin to emerge early in life, and those raised in different childhoods, such as urban and rural settings with various childhood conditions, may develop distinct exploration preferences. However, existing research presents conflicting evidence: some studies suggest that lower-quality early experiences lead to a heightened sensitivity to risk or stress, resulting in a tendency toward over-exploitation, while others argue that higher-quality early experiences can promote cognitive development, enabling children to exhibit a more adult-like, exploitative tendency. To investigate the impact of early life experiences on explore-exploit decisions, we compared the responses of urban and rural children in an explore-exploit task within a reward collection game. Our findings indicate that urban children tend to favor exploitation and achieve better reward performance. These rural-urban differences highlight the need for further research into how cognitive maturity and developmental stage shape explore-exploit choices, with the potential for extending these findings across a range of scenarios.

Keywords: explore-exploit trade-off; early experience; rural-urban differences

Introduction

Decisions between exploration and exploitation apply widely across diverse domains of daily life, requiring individuals to choose between exploring unknown options versus exploiting familiar ones (Cohen et al., 2007; Wilson et al., 2021; Mehlhorn et al., 2015). For example, an individual's career development needs to balance maintaining flexibility and increasing specialization. On the one hand, more exploitative options tend to lead to a steady reward level but may result in the agent being stuck in a "good enough" state due to the more constrained nature of such options. On the other hand, a broader and more exploratory search strategy may increase the potential for achieving a better outcome but can also create higher uncertainty at the same time (Schulz et al., 2018; Stojić et al., 2020; Wu et al., 2018; Wilson et al., 2014).

From early life, we start to make decisions about exploration and exploitation (Kim and Carlson, 2024; Gopnik, 2020). Research shows that younger agents are often regarded as better explorers, who are more willing to bear exploration costs compared to older agents (Blanco and Sloutsky, 2021; Schulz et al., 2019). This tendency to explore sometimes allows them to discover things that older agents may have missed (Liquin and Gopnik, 2022; Sumner et al., 2019; Plebanek and Sloutsky, 2017). As we age, we tend to rely more on our accumulated knowledge, leading to a shift from exploration to exploitation over the course of our lives (Brown et al., 2022; Spreng and Turner, 2019). This developmental trajectory is akin to a "cooling off" tendency, where individuals progressively reduce exploration and gradually limit their choices to a narrower range of options (Gopnik et al., 2017; Spreng and Turner, 2021).

Childhood is often regarded as a supportive and protected period where resources and support are primarily provided by others. This characteristic of childhood encourages children to broadly explore and have higher flexibility (Gopnik, 2020). Childhood conditions vary widely, and these unique early-life experiences shape individuals differently, influencing their behaviors and decision-making later in life (Frankenhuis and Nettle, 2020; Ellis et al., 2022; Shonkoff et al., 2012). For instance, in Humphreys et al. (2015), individuals who had institutional care followed by adoption tend to be more exploitative and less exploratory than those who possess common childhood experiences of growing up within their own families. In addition, consistent with the stress acceleration hypothesis (Callaghan and Tottenham, 2016), early adverse or stressful experiences could be associated with accelerated brain maturation and reduced cognitive flexibility (Harms et al., 2018), resulting in less exploration and more exploitation (Matisz et al., 2021; Lenow et al., 2017). These theories and evidence lead us to speculate that children with a lower-quality early experience shift from exploration to exploitation earlier than children with a richer-quality early experience.

Variations in early life experiences are shaped by a wide range of factors. In this study, we focus on the rural-urban gap, influenced by geographical differences between living in rural and urban areas. Evidence shows that rural and urban environments play a significant role in shaping individuals' early experiences and developmental conditions (Oguzturk, 2008; Crouch et al., 2020). Compared with rural areas, urban areas tend to have higher resource availability, richer educational opportunities, and lower poverty levels (Miller et al., 2013; Miller et al., 2019). These differences in childhood conditions between rural and urban children can be considerably characterized by childhood socioeconomic status (SES), involving factors such as parental education, occupation, and family income (Bradley and Corwyn, 2002; Peverill et al.,

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2021). Here, we investigate the effect of rural and urban early experiences on children's tendency to explore and exploit.

As mentioned above, research indicates that rural children who experience lower-quality early conditions may exhibit lower exploration and more exploitation. However, there is some contradictory evidence suggesting that greater early experiences can also be a factor that reduces one's exploration. That is, greater early experiences can improve brain development (Noble et al., 2015; Farah, 2017; Rakesh et al., 2023) and enhances one's cognitive abilities (Ellwood-Lowe et al., 2022; Tine, 2014; Lawson et al., 2018; Lurie et al., 2021). This high level of cognitive maturity may lead children's behavior to resemble that of adults, leading them to favor exploitation over exploration. Evidence like this leads us to hypothesize that urban children, who have greater early experiences, develop efficient solutions earlier than their rural counterparts. As a result, they are more likely to make exploitative and goal-directed decisions, opting for familiar, cost-effective strategies over the high-risk, high-cost exploration required to navigate explore-exploit trade-offs.

Therefore, existing evidence reveals a paradox in how early life experiences influence explore-exploit decisions: the same early condition can give rise to divergent tendencies toward exploration, leading to different patterns of explore-exploit decision-making. That is, some research shows that stress or poor early experiences can accelerate brain maturation (e.g., Matisz et al., 2021), resulting in a decrease in exploration and an increase in exploitation. On the contrary, greater early experiences can also be a factor that improves brain development and cognitive ability (e.g., Rakesh and Whittle, 2021), thereby reducing high-cost exploration and promoting more exploitation. Building on these contrasting findings, we also found that most of the evidence arguing for the supporting role of negative early experiences in increasing exploitation comes from risk-related or stress-related decision-making contexts (e.g., Humphreys et al., 2015), whereas research supporting the hypothesis that positive early experiences increase exploitation tends to focus on cognitive development. The explore-exploit task scenario used in the current study does not involve risk or stress, which may offer a new cognitive perspective for understanding the differences in exploration preferences between rural and urban children with varying early life experiences.

Overall, in the current study, we compare the differences in the explore-exploit decisions between rural and urban children. The primary reason for this comparison is that children from these two groups have distinct differences in their childhood conditions and growth environments, contributing to them having lower-quality or higher-quality early experiences. The comparison can help us understand the effect of early experiences on children's explore-exploit decisions. We employed a modified version of a spatially correlated multi-armed bandit game designed for participants to search and collect rewards (Wu et al., 2017). In our experiment, children have to make a series of decisions of whether to explore, by clicking on new tiles with unknown rewards, or to exploit, by clicking on tiles they have already clicked before, i.e., tiles with known rewards. This task is suitable for studying children's behavior of exploration and exploitation because we present them with a situation where there is no risk of loss, no time pressure, and no other constraints.

Methods

Participants

Two groups of participants were recruited from a rural place in Fujian (Rural group) and Beijing, a major urban city (Urban group). We obtained informed consent from the children's parents. After the consent form was signed, the children were allowed to participate in the experiment. We also asked parents to complete a basic demographic questionnaire, which included items related to socioeconomic status (SES), such as the annual family income and parental educational level. The rural group contains 54 children (27 females, age range = 7.17 to 8.09, Mean age = 7.66) and the urban group contains 48 children(21 females, age range = 7.03 to 8.24, Mean age = 7.63). 4 children (3 were from the rural group and 1 was from the urban group) were removed from the analysis because they failed to complete the comprehension question. The analysis is done on data collected from the remaining 98 children. The socioeconomic status information between rural and urban families is shown in Table 1.

Table 1: Socioeconomic status (SES) information between rural and urban families

Group	Rural	Urban
Family income (ten thousand RMB)		
1-3	31.37%	0%
3-5	19.61%	0%
5-10	23.53%	4.26%
10-20	21.57%	10.64%
20-50	3.92%	51.06%
$>$50	0%	34.04%
Parantal educational level		
Middle school or below	58.82%	0%
High/Vocational school	33.33%	2.13%
Associate degree	7.84%	6.38%
Bachelor's degree	0%	61.70%
Master's degree	0%	25.53%
Doctorate	0%	4.26%

Task

The explore-exploit task contains a clicking game for children to search and collect rewards, which was revised from a spatially correlated multi-armed bandit paradigm originally presented by Wu et al. (2017). In our experiment, we present children with a total of 64 tiles in a 8×8 grid world (see Figure 1). Each tile contains a certain number of rewards, with the reward ranging from 1 to 32. The reward of a tile is assigned following a "smooth" rule, which states that nearby

tiles have similar rewards. The tiles have different colors depending on the reward they contain, with tiles containing greater rewards having darker colors. The rewards of tiles were hidden from children initially, with all the tiles displaying a gray color. Children can interact with this grid world by clicking on one tile at a time, revealing and collecting the reward of that tile. When a tile is clicked on for the first time, its color changes from gray to its assigned color, which signifies its reward. The tiles that have already been clicked on will remain in their assigned color and can be clicked on again. After every click, children receive information about the amount of reward they received in this click, the total amount of reward they have received, and the number of clicking opportunities left for this round. Children were told that they needed to engage in 3 rounds of the game, aiming to maximize their total rewards within 25 clicks per round. The distribution of rewards is different in these 3 rounds. In this task, children can click on a new tile (exploration) or re-click an already-revealed one (exploitation), representing two distinct options in the explore-exploit decision process. Children's behavioral patterns, as well as the total rewards they earned, are assessed.

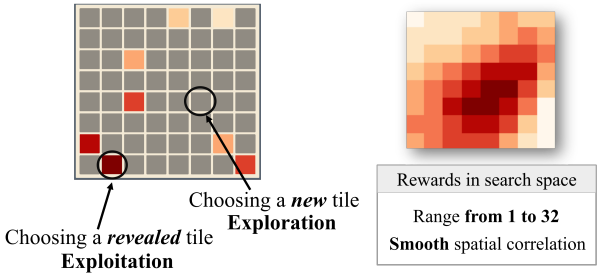

Figure 1: Explore-exploit task design. A 8×8 grid world where children can search and collect rewards. Darker-colored tiles have greater rewards. Children could choose a new tile (exploration choice) or choose a revealed one (exploitation choice). Choosing a new tile changes the tile to its assigned color. Possible reward of a tile ranges from 1-32, and the grid world has a smooth spatial correlation.

Procedure

Our study comprised four sequential phases: the instructional phase, the practice phase with a comprehension test, and the play phase with a post-game questionnaire. Both rural and urban children followed the same procedure and completed the same tasks.

Instructional phase In the instructional phase, the experimenter explained the goal and rules of the task to the children. The experimenter made two emphases: (1) darker-colored tiles contain higher rewards, and (2) any tile could be re-clicked multiple times. Then, to help children better understand the rules, the experimenter gave simple demonstrations correspondingly: (1) The experimenter showed a picture that four revealed tiles with different colors in the whole grid world and told children that these were several example tiles with their respective colors and rewards. (2) The experimenter demonstrated the behavior of repeatedly clicking on a tile and told children that this behavior was allowed but not mandatory. Finally, children were told that their goal was to accumulate as many total rewards as possible in a total of 3 rounds, with each round offering 25 clicking opportunities.

At the end of the instructional phase, children were asked to repeat the goal of the task and the rules they were told, with a particular focus on the two key rules. If the child was unable to correctly repeat the rules, the experimenter would explain to the child one more time. After that, if the child still could not repeat the rules, the experimenter would take note of that. All children were allowed to continue to the next phase.

Practice phase and the comprehension test After the instructional phase, children play one round of the game as practice. After the practice, children complete a comprehension test to confirm that they have truly understood the rules. This test includes 2 questions assessing children's understanding of the relationship between the shades of the colors and the number of rewards, as well as 2 questions evaluating their understanding of the rule regarding whether re-clicking one revealed tile is allowed. Only children who answer all the questions correctly are valid and included in the final analysis. In total, 3 rural children and 1 urban child in our study failed the comprehension test, and their data were ruled out.

Play phase and post-game questionnaire After the practice phase and the comprehension test, children enter the formal play phase. The formal game contains a total of 3 rounds, with each round having 25 clicking opportunities. The total rewards would be accumulated from these 3 rounds. The goal is to earn as many total rewards as possible.

After the children finished all 3 rounds of the game, the experimenter asked children some questions about their thoughts and feelings on the game, which helped us have a better understanding of children's motivation and preference for explore-exploit decisions (see Figure 2).

Item	Choices
What is the highest value of rewards you have found?	
Will there be higher rewards you haven't found?	
How funny do you think this game is?	
How willing are you to play the same game again?	
How willing are you to play a similar game?	
How willing are you to play a different game?	
Forced choice from the same, similar, and different game	

Figure 2: Items in the post-game questionnaire.

Results

Rural children explore more and have prolonged exploration periods than urban children

To assess children's preference for exploration, we first focused on their exploration ratio in each round. The exploration ratio is defined as the percentage of chosen tiles that

are new tiles (number of exploration choices / 25). We ran a generalized linear regression analysis with random subject effects to assess the differences in exploration ratio in rural and urban children. Our results showed that rural children (exploration ratio = 87.01 % on average, SD = 0.18) had a significantly higher exploration ratio than urban children (exploration ratio = 70.72 % on average, SD = 0.22; β = -0.14, 95% CI [-0.22, -0.06], $t(286)$ = -3.44, $p < .001$; Figure 3A). Both rural and urban children did not change their exploration ratio throughout the three rounds of the game (see Figure 3B).

To further examine children's exploration preferences, we looked at the first shift point from exploration to exploitation, defined as the first time children repeatedly chose one revealed tile (exploitation choice). Using this metric, we found that rural children, on average, made this first explore-to-exploit shift on the 16.77th clicks (SD = 8.32), which is slower than urban children (shifting on the 12.50th on average, SD = 6.60), β = -4.21, 95% CI [-7.23, -1.19], $t(286)$ = -2.74, p = .006 (see Figure 3C). There is no difference in the first shift point among the 3 rounds, both in rural and urban children (see Figure 3D). These results suggested that rural children tend to have more exploratory engagement than urban children. That is, rural children explored more and had longer exploration periods than urban children. The exploration trends of urban and rural children remained almost the same across rounds, indicating that no familiarity effect occurred at this task.

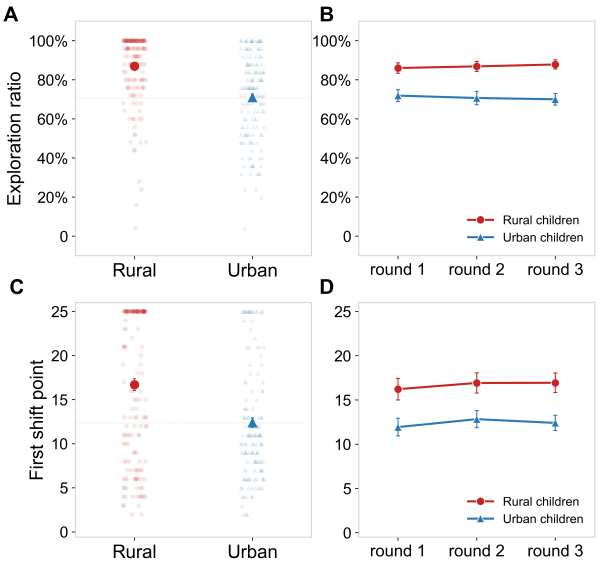

Figure 3: Exploration ratio and first explore-to-exploit shift point. (A) shows that urban children's exploration ratio was less than that of rural children. (B) shows the differences in the exploration ratio within 3 rounds in these two groups. (C) shows that urban children's first shift point was faster than that of rural children. (D) shows the differences of the first shift point within 3 rounds in these two groups.

Urban children adopted a narrower yet seemingly more adaptive pattern to the search space

In addition to distinguishing between repeated (exploitation choice) and non-repeated clicking (exploration choice), we also aim to understand the exploration patterns of rural and urban children in more detail. Another important reason for this is that the search space is a structured one that can be learned. Looking at the ways in which children explore can know how children learn and adapt these search spaces. We analyzed the distances between consecutive choices of clicks. That is, we asked how many times a child clicked the exact same tile that they just clicked (Repeat), any of the tiles in the neighboring circle (Near), any of the tiles in farther rings (Far) (see Figure 4). We analyzed the group frequency of these 3 patterns using a generalized linear regression with random subject effects. Our results showed that, firstly, rural children (1.21 times on average, SD = 3.38) made much fewer Repeat choices than urban children (3.94 times on average, SD = 5.33), β = 1.92, 95% CI [0.15, 3.68], $t(286)$ = 2.13, p = .034, and this differential pattern holds across the 3 rounds. Rural children (7.14 times on average, SD = 5.76) also made fewer Near choices than urban children did (9.44 times on average, SD = 5.13), β = 2.78, 95% CI [0.60, 4.96], $t(286)$ = 2.51, p = .013. Additionally, both rural and urban children gradually increased their Near choices by rounds 3 (overall, M_{round1} = 7.72, M_{round2} = 8.27, M_{round3} = 8.74, β = 1.55, 95% CI [0.36, 2.74], $t(286)$ = 2.57, p = .011), suggesting that they developed a certain degree of learning about the features of search space. Finally, rural children (15.64 times on average, SD = 6.05) made much more Far choices than urban children did (10.62 times on average, SD = 5.17), β = -4.69, 95% CI [-6.95, -2.44], $t(286)$ = -4.10, $p < .001$. Overall, this analysis showed that urban children made more Repeat and Near choices and fewer Far choices than rural children. In short, urban children's search pattern is narrower and more adaptive given the smooth search space environment, resulting in their accumulated greater rewards. Still, rural children could adapt to the smooth search space gradually, increasing their Near choices and reducing Far choices from round 1 to 3.

Urban children earned higher rewards than rural children

Other than comparing children's exploration behaviors, we also looked at their reward performance. Our results showed that urban children (1641.36 rewards on average, SD = 170.54) earned higher total rewards than rural children did (1447.73 rewards on average, SD = 178.15), $t(96)$ = -5.50, $p < .001$, d = -1.12. We visualized average reward performance over trials between rural and urban children in each round (see Figure 5A, B, and C). We observed that as the trials progressed, the rewards performance of urban and rural children gradually diverged, with the performance of urban children surpassing that of rural children (β = 2.58, 95% CI [1.66, 3.50], $t(7344)$ = 5.49, $p < .001$). We continued to visualize the correlation between rewards obtained on previ-

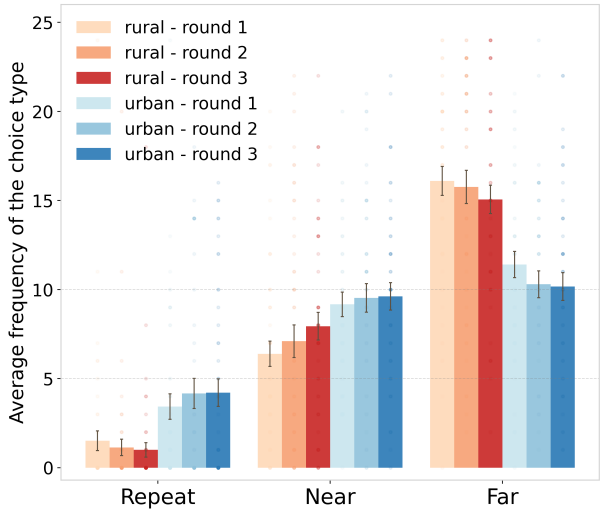

Figure 4: Frequency of 3 types of distances between consecutive choices (including repeat, near, and far) in rural and urban children: compared to rural children, urban children more frequently made the narrow range of choices rather than the farther ones.

ous choices and the distance of subsequent choices (see Figure 5D, E, and F). From the different slopes of the regression lines, we could observe that, compared to rural children, the search range of urban children is more significantly influenced by the value of the reward obtained in the previous choice. That is, urban children tended to narrow their search more quickly when they revealed the high-reward tiles.

Urban children were more willing to play a new game compared to rural children

In the post-game questionnaire, we asked children if they were willing to play the same game, a similar game, or a different game using a 5-point scale (from 1 = not willing at all to 5 = extremely willing). We found that both rural and urban children were equally willing to play the same game again, M_{rural} = 4.47, M_{urban} = 4.68, $t(85.68)$ = -1.55, p = 0.126, d = -0.33. However, urban children had a higher willingness to play a similar game and a different game, than rural children did (for a similar game, M_{rural} = 3.98, M_{urban} = 4.51, $t(84.08)$ = -3.16, p = 0.002; d = -0.69; for a different game, M_{rural} = 3.53, M_{urban} = 4.26, $t(94.34)$ = -3.17, p = 0.002; d = -0.65, see Figure 6A). When asked to choose between these 3 types of games (same, similar, or new), most urban children (51.06%) chose a new game, while most rural children (39.21%) tended to choose a similar game (see Figure 6B).

Conclusion and Discussion

How do the rural vs. urban contexts influence children's explore-exploit decisions? Our current findings suggest that rural children tended to explore more and longer than urban children. In the process of searching and collecting rewards,

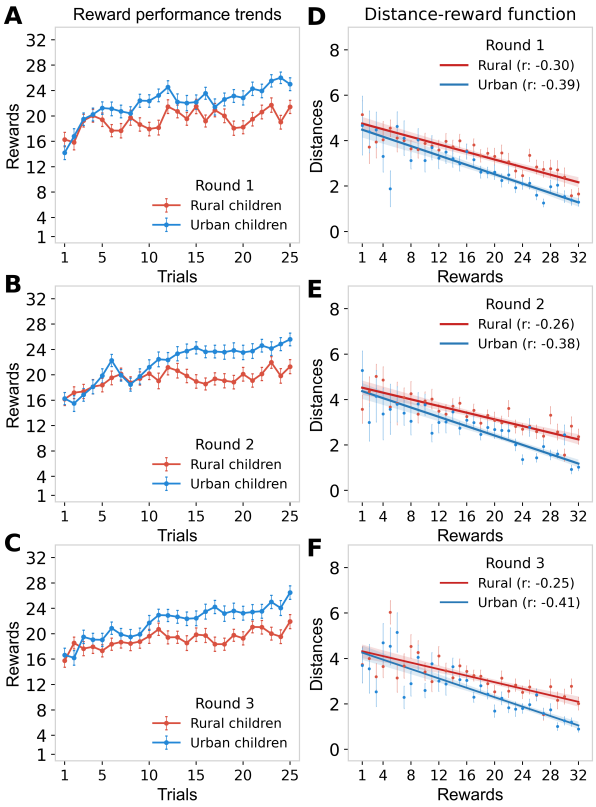

Figure 5: Children's reward performance over trials and the distance-reward function in their consecutive choices: Urban children performed better than rural children with trials, similar within 3 rounds (A-C). Distance as a function of rewards for consecutive choices shows that urban children were more sensitive to their rewards than rural children, similar within 3 rounds (D-F).

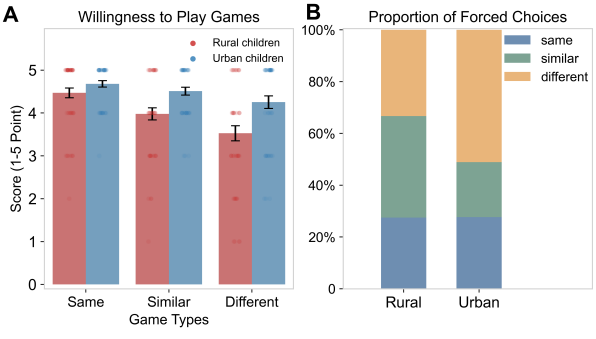

Figure 6: Some results in the post-game questionnaire. (A) Rural and urban children's willingness to continuously play three different types of games (same, similar, and different). (B) The proportion of rural and urban children's forced choices among these three types of games to continue playing.

urban children were more likely to make a narrower range of searches, choosing nearby tiles or clicking a previously clicked tile. In contrast, rural children were more likely to click tiles that were far away from their previous click. These results show an overall difference in exploration behaviors between rural and urban children, supporting the hypothesis that urban children are less exploratory and more exploitative than rural children. This tendency observed in our results contradicts the assumptions of traditional theories (e.g., Matisz et al., 2021; Lenow et al., 2017), which support that urban children, with better growth conditions and richer resources, should explore more than their rural counterparts.

One possible explanation is that the task used in our study may not have triggered the cognitive states that typically arise in risk or stress situations, whereas much prior research focused on such contexts. For example, in our experimental task, children were not under time pressure, nor did they face competition or social comparison, and there was no risk of losing rewards. And in our study, almost all of the children, whether rural or urban, thought the task extremely funny and were willing to play again. This could support that the children's attitude towards the task was relaxed. Future studies examining rural-urban differences in children's explore-exploit decisions in more risk-laden or stressful contexts would provide valuable insights.

Another possible explanation for the differences between rural and urban children could be related to cognitive development. Our results show that urban children earned higher rewards and performed better than rural children, suggesting that urban children achieved the goal of the task better. This difference in performance is also reflected in their exploration strategies. Urban children, compared to their rural peers, were better able to adjust their choices based on the rewards they had previously obtained. Additionally, urban children explored the search space more selectively, rather than extensively. Since the search space has learnable features and rules, a more limited exploration is actually a more adaptive approach than a broad and long search. This more adaptive exploration strategy, along with the better reward performance, may indicate higher cognitive abilities in urban children. These findings suggest that the developmental gap in cognitive abilities between rural and urban children, which could be supported by the evidence that varying childhood conditions (e.g., SES) can shape cognitive development (e.g., Bradley and Corwyn, 2002; Lurie et al., 2021).

Interestingly, in our post-game questionnaire, both rural and urban children expressed a desire to try new games they hadn't played before, but their preferences for novelty and unfamiliarity differed: Rural children preferred games with moderate novelty, while urban children were more inclined to explore games with higher novelty. Additionally, urban children showed a greater willingness to try a different game compared to their rural counterparts. These findings suggest that urban children may be more open to exploring unfamiliar options.

This differential pattern—that urban children are more exploratory than rural children did—could emerge because there was no apparent cost for exploration. Moreover, during the post-game phase, the experimenter asked the children a few simple questions, revealing that some rural children viewed unfamiliar games as more challenging and predicted poor performance, which seemed to lower their willingness to try. In contrast, urban children were more confident in their ability to try different games, possibly reflecting higher self-confidence. While these hypotheses remain untested in the current study, they warrant further investigation. These findings provided us with another view to look at the features of children's exploration.

In short, our study makes a new contribution in showing the rural-urban differences in children's explore-exploit decisions: urban children tend to be less exploratory and more goal-directed than rural children. This trend contradicts ideas supported by the life-history theory and stress acceleration hypothesis, suggesting that poorer early experiences hinder exploration.

However, the rural-urban differences in our study conform to the assumptions that poorer early experiences can inhibit children's cognitive performance. Our results encourage us to further consider the internal cognitive factors underlying explore-exploit decisions. In addition to preferences like "I love to explore" and motivations such as "I want to explore", the factors that determine an individual's exploration behaviors may also be linked to the strategy of "I need to explore", especially in the explore-exploit decisions. This aspect involves how individuals approach task goals and solve the problem, largely associating with one's cognitive abilities. Indeed, the natural goal in explore-exploit decisions is typically related to achieving a greater reward performance, which may be separate from the goal of seeking information that more characterizes exploration for learning. Exploration is an inherent trait and a preferred behavior in early life. As individuals grow, they may begin to focus on more specific goals, adjusting their responses in different situations. The differences in explore-exploit decisions between urban and rural children may reflect the effect of various developmental speeds on cognitive abilities, thereby influencing their explore-exploit decisions. Further research is needed to deepen our understanding of the cognitive and developmental mechanisms involved in explore-exploit decisions, with the potential for expanding it into multiple scenarios.

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