Preserved Curiosity-Driven Learning in Children with Communication and Behavioural Difficulties

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Introduction

Epistemic curiosity is defined as the intrinsic desire to acquire knowledge for its own sake, driven by the desire to understand rather than external rewards, and it is a fundamental drive shaping learning across development. States of curiosity not only motivate information-seeking behaviour, such as asking questions to clarify a topic and gain new knowledge on said topic, but also enhance memory through dopaminergic reward circuits and hippocampal engagement (Kang et al., 2009; Gruber et al., 2014; Fandakova & Gruber, 2020). Moreover, curiosity-driven learning can be conceptualised within the PACE (Prediction, Attention, Curiosity, and Explanation) framework, where unexpected events, or prediction errors, trigger enhanced attention, information seeking, and memory consolidation (Gruber & Ranganath, 2019; Marvin & Shohamy, 2016; Garvin & Krishnan, 2022).

While these mechanisms have been studied primarily in neurotypical populations, curiosity appears preserved in some atypical groups. For example, McGeown et al. (2012) found reduced self-reported curiosity for reading in poor readers, yet Garvin & Krishnan (2022) demonstrated that adults with dyslexia still expressed curiosity and information-seeking behaviours comparable to controls, though memory benefits were attenuated. Whether similar patterns are observed in children with communication and behavioural difficulties remains unclear, however, which is why we have decided to investigate children for our study.

Children with communication and behavioural difficulties represent a heterogeneous population that may include those with autism spectrum conditions, attention difficulties, language impairments, and social communication challenges. This population of children is of particular interest for studying curiosity because the core components of the PACE framework (such as processing surprises, regulating attention, and engaging in exploratory behaviour) may be directly challenged by these difficulties. For instance, differences in sensory processing or social cognition could affect how prediction errors are generated, while attention difficulties could disrupt the subsequent attentional shift. Similarly, behavioural challenges related to motivation or impulse control could impact the willingness to explore. Therefore, investigating whether curiosity-driven learning is preserved in this group provides a strong test of the robustness of the PACE mechanism.

Traditional research approaches have typically compared discrete diagnostic categories, but this presents several limitations: small sample sizes within categories, heterogeneity within diagnostic groups, and the challenge of studying children who may not meet full diagnostic criteria but still experience significant difficulties.

We investigated four key research questions: (1) Do children with greater communication and behavioural difficulties express similar levels of curiosity for new information? (2) Are they equally willing to invest time waiting for information they find curious? (3) Do they experience similar curiosity-driven memory benefits? (4) How do visual versus verbal stimulus modalities affect these processes?

And our hypothesis was that that epistemic curiosity systems would be largely preserved across the developmental spectrum, based on their fundamental role in learning and adaptation. However, we anticipated possible modality-specific differences, with visual information potentially showing advantages over verbal information for children with communication difficulties.

Methods

Participants

Thirty-six children aged 8-12 years (M = 9.98, SD = 0.85; 17 male, 18 female) participated in this study. Children represented a range of developmental profiles, from neurotypical development to those with diagnosed or suspected neurodevelopmental conditions.

Children were included if they were native UK English speakers with normal vision and hearing (corrected if necessary), and were excluded if they had a diagnosis of ADHD, epilepsy, genetic conditions, or any other condition that might affect learning beyond communication and behavioural difficulties.

Seven participants (14%) were excluded due to missing composite scores, and seven participants (14%) due to missing age data, with some overlap between these groups. The final analysis sample represented 72% of the total recruited sample (N = 50). Children with missing data did not differ significantly from those with complete data on available demographic variables.

Measures

Dimensional Composite Variable

This study consitutes a secondary analysis of an existing dataset. We created a latent variable representing communication and behavioural functioning using three standardised questionnaires completed by parents.

Firstly, the Social Communication Questionnaire (SCQ), which measures autism spectrum symptoms across lifetime and current time periods, with higher scores indicating more autism-related difficulties.

Secondly, the Children's Communication Checklist-2 (CCC-2), which assesses communication skills and pragmatic language abilities. We used the General Communication Composite (GCC) and Social Interaction Deviance Composite (SIDC), with lower GCC scores indicating greater communication difficulties.

And lastly, the Strengths and Difficulties Questionnaire (SDQ), which measures behavioural and emotional functioning, often used as an indicator of mental health challenges. We used internalising and externalising behaviour subscales, with higher scores indicating more difficulties.

Using factor analysis, we confirmed these measures loaded onto a single factor (eigenvalue = 2.76, 46% variance explained) and created a standardised composite score where higher values indicate greater communication and behavioural difficulties ($M = 0.018$, $SD = 1.09$, range = -3.11 to 1.91). This dimensional approach allows examination of curiosity-driven learning across a continuum of functioning rather than comparing discrete diagnostic categories, allowing for better statistical analysis, and accounting for the issue of lack of diagnoses at a young age.

Curiosity-Driven Learning Task

We employed a willingness-to-wait paradigm conducted across two sessions separated by approximately 1 week. Session 1 involved the primary experimental task measuring curiosity, decision-making, and satisfaction. Session 2 focused on memory assessment for information encountered in Session 1.

Session 1: Curiosity and Decision-Making Task

Each trial followed a standardised pattern:

1. **Question Presentation** (5 seconds): Participants viewed a trivia question and were instructed to think about whether they knew the answer.
2. **Decision Phase** (self-paced): Participants chose between three options:
    a. "Skip" - Move to the next question without learning the answer
    b. "Wait" - Wait to learn the answer (with predetermined wait times)
    c. "Know" - Indicate they already know the answer
3. **Wait Period** (if "Wait" selected): Participants waited for a predetermined duration (10, 15, 20, 25, or 30 seconds) before the answer was revealed.

4. **Answer Revelation** (3 seconds): The correct answer appeared on screen for all "Wait" and "Know" trials.
5. **Curiosity Rating** (self-paced): Participants rated their curiosity about the question on a 7-point Likert scale (1 = "Not at all curious" to 7 = "Extremely curious").
6. **Satisfaction Rating** (self-paced, for "Wait" and "Know" trials only): Participants rated their satisfaction with learning the answer on a 7-point Likert scale (1 = "Not at all satisfied" to 7 = "Extremely satisfied").

Session 2: Memory Assessment

Approximately 1 week after Session 1, participants returned for memory testing. For each item, participants completed a 4-alternative forced-choice recognition test. Memory analysis focused on 665 trials where children chose to wait, from 35 participants.

Statistical Analysis

We used mixed-effects models to account for the nested structure of trials within participants and items. Linear mixed-effects models (lmer) were used for continuous outcomes (curiosity ratings) and generalised linear mixed-effects models (glmer) with binomial family for binary outcomes (waiting decisions, memory accuracy).

All models included random intercepts for participants and items, with fixed effects for the composite skill measure, stimulus type (visual vs. verbal), and child age. Age was included as a covariate in all models to control for developmental effects. The composite skill measure was treated as a continuous predictor, with higher values indicating greater communication and behavioural difficulties.

Statistical significance was set at $\alpha = 0.05$. All analyses were conducted in R using the lme4 and lmerTest packages.

Results

Sample Characteristics

The final analytic sample included 1,440 trials from 36 participants across 40 experimental items. The composite skill measure showed good distribution across difficulty levels, with representation across the full spectrum of communication and behavioural functioning.

Four children (11%) were multilingual. The composite score distribution confirmed adequate representation across difficulty levels, ranging from very low difficulties (few communication/behavioural challenges) to high difficulties (more substantial challenges).

Research Question 1: Curiosity Expression

Children with greater communication and behavioural difficulties showed equivalent curiosity expression to those with fewer difficulties ($\beta = -0.074$, SE = 0.124, $t(33) = -0.59$, $p = 0.557$). This small, non-significant coefficient indicates that the severity of difficulties was not systematically associated with curiosity ratings.

Visual stimuli elicited slightly higher curiosity than verbal stimuli ($\beta = 0.125$, SE = 0.100, $t(38) = 1.26$, $p = 0.217$), but this effect did not interact with difficulty level ($\beta = 0.010$, SE = 0.072, $t(1364) = 0.14$, $p = 0.892$). Age was not significantly associated with curiosity ratings ($\beta = -0.014$, SE = 0.159, $t(33) = -0.09$, $p = 0.932$).

The near-zero coefficient with narrow confidence intervals suggests preserved curiosity expression across the developmental spectrum. If communication and behavioural difficulties substantially impaired curiosity, we would expect a negative relationship (more difficulties = less curiosity). Instead, we found no systematic relationship.

Research Question 2: Willingness to Wait for Information

All children showed strong relationships between curiosity and willingness to wait ($\beta = 0.378$, SE = 0.043, $z = 8.86$, $p < 0.001$), with higher curiosity dramatically increasing the probability of choosing to wait (OR = 1.46).

Critically, difficulty level was not associated with willingness to wait ($\beta = 0.014$, SE = 0.128, $z = 0.11$, $p = 0.913$), indicating that children across the difficulty spectrum were equally willing to invest time for information they found curious. Age was not significantly associated with waiting behaviour ($\beta = 0.061$, SE = 0.165, $z = 0.37$, $p = 0.712$).

The preservation of curiosity-waiting relationships across difficulty levels suggests that information-seeking motivation remains intact regardless of communication and behavioural challenges. The strong curiosity effect demonstrates that all children, regardless of difficulty level, were motivated to seek information they found interesting.

Research Question 3: Memory Enhancement

Memory analysis focused on 665 trials where children chose to wait, from 35 participants. Children showed a marginal curiosity-memory relationship ($\beta = 0.138$, $SE = 0.071$, $z = 1.95$, $p = 0.052$), consistent with previous research on curiosity-driven memory benefits.

We found no significant negative relationship between difficulty level and memory performance ($\beta = 0.259$, $p = 0.110$). The direction of this non-significant trend was unexpectedly positive, suggesting that memory mechanisms are not only preserved but that children with greater difficulties may show a tendency toward enhanced performance, a finding that warrants further investigation in larger samples.

Age was not significantly associated with memory performance ($\beta = 0.013$, $SE = 0.203$, $z = 0.06$, $p = 0.949$).

The lack of negative associations between difficulty level and memory performance, combined with the marginal curiosity-memory effect, suggests that curiosity-driven learning mechanisms remain functional across the developmental spectrum.

Research Question 4: Modality Differences

Visual and verbal stimuli showed generally similar patterns across all measures. The interaction between difficulty level and stimulus type was not significant for any outcome measure, suggesting that the preservation of curiosity systems was consistent across both visual and verbal information.

Discussion

Preserved Epistemic Curiosity Systems

Across curiosity expression, willingness to wait, and memory, we found preserved curiosity-driven learning despite varying difficulty severity. This aligns with research showing that curiosity enhances memory through reward-related dopaminergic–hippocampal interactions (Kang et al., 2009; Gruber et al., 2014; Fandakova & Gruber, 2020). Our findings extend those of Garvin & Krishnan (2022), who showed that adults with dyslexia express intact curiosity but reduced curiosity-related memory benefits, by demonstrating that children with broader communication and behavioural difficulties also maintain curiosity systems.

Methodological Innovations and Advantages

Our dimensional approach offers several advantages over traditional categorical comparisons. First, it provides larger effective sample sizes by avoiding the arbitrary boundaries of diagnostic categories. Second, it reduces within-group heterogeneity by creating more homogeneous groupings along relevant dimensions. Third, it allows examination of subclinical presentations that might not meet diagnostic thresholds but still represent meaningful individual differences.

The latent variable approach also captures the reality that communication and behavioural difficulties often co-occur and exist on continua rather than as discrete categories. This may be particularly relevant for understanding learning mechanisms that operate across various neurodevelopmental conditions.

Absence of Age Effects

Unlike previous research focusing on broader developmental periods, our study within the 8-12 year age range revealed no significant age effects on curiosity, waiting behaviour, or memory performance. This suggests that while curiosity systems may undergo broader developmental changes across childhood, they remain relatively stable within middle childhood regardless of individual differences in communication and behavioural functioning.

Unexpected Memory Findings

The marginal trend toward better memory performance in children with greater difficulties ($\beta = 0.259$, $p = 0.110$) warrants careful interpretation. While not statistically significant, this positive coefficient was unexpected and suggests that compensatory mechanisms or heightened engagement might occur in some children with communication and behavioural challenges. This finding requires replication but aligns with research suggesting that some neurodevelopmental differences may be associated with enhanced performance in specific domains.

Implications for Educational Practice

The preservation of curiosity-driven learning mechanisms has important practical implications. Since children across the developmental spectrum show similar responses to curious information, curiosity-based educational interventions should be broadly effective. Rather than requiring specialised approaches for different difficulty profiles, educators might focus on identifying and leveraging individual children's areas of curiosity.

This finding aligns with person-centered educational approaches that emphasise individual interests and strengths rather than deficit-focused interventions. It suggests that curiosity represents a potential avenue for engagement even when other learning systems may be challenged.

Limitations and Future Directions

Several limitations should be considered. First, our sample size of 36 participants, while adequate for mixed-effects analyses, may have limited our ability to detect small effect sizes. However, our confidence intervals suggest adequate precision for meaningful conclusions about preservation versus impairment.

Second, our task focused on trivia-style factual information. Future research could examine whether curiosity preservation extends to other domains such as procedural learning, social information, or academic content areas.

Third, our dimensional approach, while theoretically motivated, represents one way of organising neurodevelopmental differences. Alternative dimensional models or inclusion of additional measures might yield different insights.

Future research could also investigate the neural mechanisms underlying preserved curiosity in neurodevelopmental conditions, examine longitudinal development of curiosity systems, and test curiosity-based interventions in applied settings.

Theoretical Implications

The preservation of epistemic curiosity across neurodevelopmental differences suggests that these systems may be relatively robust to the types of difficulties measured in our composite. This could reflect the fundamental importance of information-seeking for survival and adaptation: curiosity systems may be evolutionarily canalised in ways that make them resistant to disruption.

Alternatively, curiosity systems might rely on different neural circuits or developmental processes than those affected by communication and behavioural difficulties. The dopaminergic reward systems underlying curiosity may be largely intact even when social communication or behavioural regulation systems show differences.

Conclusions

This study demonstrates that epistemic curiosity and information-seeking behaviours remain preserved in children with communication and behavioural difficulties. Using a dimensional approach with rigorous age controls and transparent missing data handling, we found no systematic negative relationships between difficulty severity and curiosity expression, willingness to wait for information, or memory benefits.

These findings challenge deficit-focused assumptions about neurodevelopmental differences and suggest that curiosity represents a robust learning mechanism that could be leveraged in educational and therapeutic contexts. The preservation of these systems across difficulty levels, combined with the absence of age effects within our sample, suggests that curiosity-based approaches may be broadly effective for children in middle childhood regardless of their communication and behavioural profiles.

Rather than focusing on deficits or developing specialised interventions for specific diagnostic categories, our findings suggest that curiosity-based approaches may be broadly effective across the developmental spectrum. This represents a shift toward strength-based, person-centered approaches that capitalise on preserved learning mechanisms.

Future research should examine curiosity preservation across broader age ranges, explore the unexpected memory enhancement trends, and investigate the neural mechanisms underlying robust curiosity systems in neurodevelopmental conditions.

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