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To cite this article: Olga Kuzmina & Margarida Romero (2025) Study of divergent thinking and task performance in children with ADHD through a modular robotic task, Australian Journal of Learning Difficulties, 30:2, 169-186, DOI: [10.1080/19404158.2025.2567849](https://doi.org/10.1080/19404158.2025.2567849)

To link to this article: <https://doi.org/10.1080/19404158.2025.2567849>



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Published online: 10 Nov 2025.



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Study of divergent thinking and task performance in children with ADHD through a modular robotic task

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ABSTRACT

This study investigates the divergent thinking components and task performance of children with Attention Deficit and Hyperactivity Disorder (ADHD) using the CreaCube task, a manipulative robotic activity. We hypothesize that children with ADHD will exhibit higher levels of fluency, flexibility, and originality in their problem-solving compared to their neurotypical peers. The study included fifteen children aged 9 to 14, including seven diagnosed with ADHD and eight controls. The CreaCube task required participants to assemble modular robotic cubes. We examined the components of divergent thinking and the time it took to solve the task. Despite finding no significant differences between ADHD and neurotypical children, behavioral observations suggest distinct exploratory patterns among participants with ADHD. These preliminary findings show the potential of robotics-based tasks for studying creative problem-solving approaches in ADHD. Through this study, we show the relevance of educational robotics for capturing the interactive nature of creativity in children with ADHD.

ARTICLE HISTORY

Received 4 August 2024

Accepted 25 September 2025

Introduction

Attention Deficit and Hyperactivity Disorder (ADHD) is recognized as the most prevalent neurodevelopmental disorder, characterized by persistent inattention, hyperactivity, and impulsivity (Rep, 2024). Approximately 8.0% of children and adolescents (Ayano et al., 2023a) and 3.10% of adults (Ayano et al., 2023a) worldwide are thought to be affected by ADHD. This condition can endure into adolescence and adulthood, posing a risk for additional mental health disorders and adverse outcomes such as poor academic achievement, social skills, and emotional regulation (Barkley, 2014).

While ADHD is a challenge in formal educational contexts, emerging evidence suggests that individuals with ADHD may exhibit unique cognitive strengths, particularly in areas of creativity and problem-solving (Hoogman et al., 2020). This evolving landscape in ADHD research is shifting from a deficit-focused perspective to one that recognizes the potential benefits of neurodiversity. The findings by Charabin et al. (2023) emphasize the

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importance of adopting a strengths-based perspective when working with children diagnosed with ADHD. The study found that children with ADHD felt they had similar levels of strengths and resilience compared to their peers without ADHD, except in school functioning. This underscores the importance of recognizing and fostering the potential strengths and resilience in children with ADHD.

The relationship between ADHD and creativity is not straightforward. Research findings are mixed, with some studies reporting enhanced divergent thinking in individuals with ADHD (White & Shah, 2006, 2011, 2016), while others report no significant differences. For example, Healey and Rucklidge (2006) found no significant differences in creativity between children with and without ADHD using both divergent thinking assessments (Torrance Tests of Creative Thinking [TTCT], Maier's Two-String Problem) and general cognitive assessments (WISC-III). Conversely, White and Shah's studies focused on divergent thinking and found that adults with ADHD exhibited higher levels of fluency, flexibility, and originality, though results varied across studies.

ADHD and creativity: a complex relationship

Creativity is a multifaceted concept defined by inventiveness and originality, leading to the generation of new ideas or novel connections that are useful within a social context (Runco & Jaeger, 2012). Theories of creativity often distinguish between divergent and convergent thinking. Divergent thinking, associated with flexibility and variety, focuses on generating numerous solutions to open-ended questions, while convergent thinking centers on finding the most fitting or original answer (Zhang et al., 2020).

Creative potential will be mostly associated with divergent thinking (Runco & Jaeger, 2012) and there is more evidence suggesting that ADHD is linked with this type of thinking abilities. For example, Boot et al. (2017) found that subclinical ADHD symptoms are associated with enhanced divergent thinking, particularly in generating original ideas. Their study suggested that the hyperactivity-impulsivity symptoms of ADHD might drive this enhancement. Some additional study confirms that higher ADHD symptoms were associated with higher scores in divergent thinking measures (fluency, flexibility, originality) but not convergent thinking (Stolte et al., 2022). Another study by Taylor et al. (2018) focused on undergraduate engineering students aimed to explore how various ADHD characteristics related to executive functioning, assessed through the Brown ADD Scales, predict different aspects of figural divergent thinking, intellectual risk-taking, and creative self-efficacy. They found a positive association with indicators of creativity, especially in figural divergent thinking. In contrast to Boot et al. (2017) results, they proposed that inattention characteristics might be better assessed through figural rather than verbal tasks, due to potential verbal memory deficits associated with ADHD.

Still there are some uncertainties in the studies and the link between divergent thinking and ADHD is not yet clarified. The results vary significantly when different aspects of divergent thinking are considered. For instance, White and Shah's studies on adults reported increased fluency, flexibility, and originality in one study, but only increased originality in another, and increased flexibility and originality in a third. These inconsistencies may be attributed to the different tasks used in the studies (White & Shah, 2006, 2011, 2016). In the study by Gonzalez-Carpio et al. (2017), children with ADHD scored significantly higher than controls in fluency, originality, and creative strengths using

Torrance Tests of Creative Thinking (TTCT), indicating greater creative potential in these areas.

Overall, the review of 31 behavioral studies on creativity and ADHD confirms potential cognitive strengths, particularly in creative thinking (Hoogman et al., 2020). Most studies indicate that individuals with elevated ADHD trait levels, but who do not meet diagnostic thresholds, exhibit greater divergent thinking than those with formally diagnosed ADHD. This suggests that subclinical ADHD symptoms may enhance creativity, especially in tasks that involve generating multiple solutions to a problem. Both clinical and subclinical groups showed high levels of creative abilities and achievements. The review highlights that ADHD traits like impulsivity and distractibility can contribute to creative performance by allowing a more flexible association network. No significant evidence was found for increased convergent thinking abilities. Convergent thinking, which requires focused and sustained attention, may be negatively impacted by ADHD-related distractibility.

Assessing creativity using modular robotics

Commonly used methods in psychology, such as the TTCT and the Alternative Uses Test (AUT), have been widely used to assess divergent thinking (Hoogman et al., 2020). While these tests provide valuable insights, they predominantly rely on semantic idea generation, which may not fully capture the dynamic and interactive nature of creative processes. In contrast, recent advancements in robotics offer novel ways to evaluate creativity, particularly through Human-Robot Interaction (HRI). The CreaCube task, for instance, involves participants in a creative problem-solving activity using modular robotic cubes, allowing for a more interactive and tangible assessment of creativity (Romero, 2019). In the CreaCube task, participants engage in building and manipulating robotic cubes to achieve specific objectives, thereby supporting creativity through physical interaction and material affordances (Romero, 2019). This method evaluates the three main components of divergent thinking – fluency, flexibility, and originality – by analyzing the configurations and transformations of the cubes during the task.

Study done by Leroy et al. (2021) investigated the relationship between creative behaviors observed in the AUT and in the CreaCube task. They found a significant difference between those and suggested that divergent creative scores from the AUT, which is based on idea generation, do not translate into creativity development through hands-on, manipulative tasks like CreaCube. This study emphasizes that creativity in technology-enhanced learning, such as programming tasks or maker-based artifacts, yields different results compared to psychometric measures like the AUT.

Leroy and Romero (2022) investigated how creative intention (whether participants intended to create a new solution in the second task) and persistence (time spent on the task) affect creative outcomes in an educational robotic task using CreaCube. They aimed to understand if participants would repeat the same solution or develop a new one in a subsequent attempt. They identified four profiles of creative behaviors: creative, conservative, non-intentional creative, and non-intentional conservative. Non-intentional creative behavior is observed when in the second occurrence of the creative problem-solving (CPS) task the participants aim to repeat the solution of the first occurrence, but they fail and need to engage in a non-intentional creative behavior in order to succeed. On the other hand, non-intentional conservative behavior is observed in participants who

try a new configuration when engaged in the second occurrence but give up on their creative intention after failing to be creative, leading them to repeat the existing solution of the first occurrences. Creative intention was a significant predictor of creative solutions, with 62% of participants who intended to be creative producing a new solution, compared to only 8.1% without creative intention. Additionally, 15.7% showed persistent creative behavior, while 9.6% initially intended to be conservative but ended up being creative due to task challenges.

Current study

In this study, we aimed to explore the divergent thinking abilities of children with ADHD by employing a creative problem-solving task. We utilized the manipulative robotic task, CreaCube, to assess the divergent thinking components of fluency, flexibility, and originality. The task required children to explore various ways to assemble the CreaCube robotic cubes to find a way to make it functional. The task was repeated twice to assess the profile of creative behavior. We hypothesize that children with ADHD will exhibit higher levels of fluency (H1), flexibility (H2), and originality (H3), providing further insight into the cognitive strengths associated with ADHD. We expect children with ADHD to spend a higher amount of time to complete both occurrences of the CreaCube task (H4). In relation to creative behavior, we expect children with ADHD to show a higher rate of non-intentional creative behavior due to the difficulties to manage the initial solution in the CPS task (H5).

Methods

Participants

Fifteen children between the ages of 9 and 14 participated in the study ($M = 10.53$; $SD = 1.59$). The group with ADHD ($n = 7$) included participants aged 9 to 13 ($M = 10.57$), and the control group with no indication of ADHD ($n = 8$) ranged from 9 to 14 ($M = 10.50$). The age distribution was relatively balanced, but due to the small sample size, we did not conduct subgroup analyses by age. Recruitment was conducted through outreach to schools, ADHD support organizations, community centers, and professionals such as psychologists and psychotherapists working with children diagnosed with ADHD. In addition to confirming that participants had no prior experience with the CreaCube system, we asked whether the child had participated in any extracurricular robotics, engineering, or STEM-focused programs (e.g. robotics clubs, coding camps). None of the participants in either group had formal training or substantial prior exposure to robotics. Although we did not explicitly match participants by age, the age distribution was comparable between the ADHD and control groups. We did not formally assess intelligence using standardized IQ tests; however, all participants were reported by parents or guardians to be functioning within the typical academic range for their age group and attending mainstream schools without additional academic support services. The group with ADHD was established by confirming that each child was diagnosed with ADHD by a psychiatrist or psychologist. All participants were right-handed, not medicated, and had no prior experience with the CreaCube task as part of the inclusion criteria. For the exclusion criteria, participants needed to have the ability to follow instructions and complete the experiment. We

informed the tutors about the study and had them sign informed consent forms to allow their children to participate in the research. The participants consented to videotape only their hands.

Materials

The materials for the CreaCube task consist of four cubes chosen from Cubelets Modular Robotic. Participants must build a vehicle that moves independently of a starting point to a finishing point (from red point to black point) as shown in Figure 1. Each cube has a different color and specific function (see Figure 2). Participants can create new configurations by assembling the four cubes. The behavior of each configuration varies depending on the position of each cube. Certain configurations have the capacity to complete the task successfully when the cubes are arranged correctly, whereas others prove unsuccessful due to particular cube combinations. By visually exploring and manipulating the cubes, participants uncover the various affordances of the objects and technology they offer. The task can be accomplished by the participant through the assembly of one of the 12 configurations that have the potential for success.



Figure 1. Modular robotic cubes and their placement.

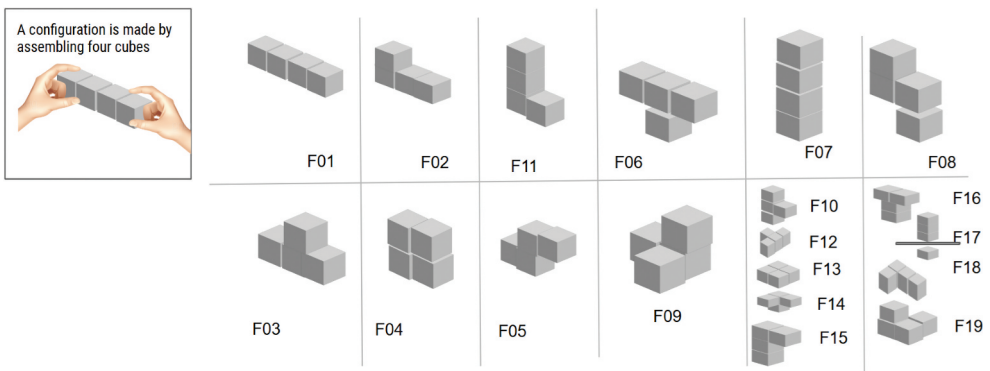


Figure 2. Configurations of the CreaCube task.

The four cubes are magnetized, and each of them has a specific function that allows to create a configuration (Köhler & Romero, 2023):

- **Wheels:** A cube composed of wheels allowing the vehicle to move when powered by the battery
- **Battery:** A cube that will provide energy to others cubes when activated (via a button)
- **Sensor:** A cube that will detect the presence of an object in front of its sensors
- **Inverter:** A cube that reverses the operation of every other cube (except the battery). As an example, the sensor will send a “positive” signal if there is nothing in front of it, instead of sending if it detects an object.

Measures

By analyzing the various configurations generated by participants, the CreaCube task facilitates the execution of flexibility, fluency, and originality components.

Fluency was defined as the total number of configurations a participant attempted, including minor changes in the position or orientation of cubes within the same functional design. These internal differences were counted toward fluency but not toward flexibility or originality. *Flexibility* was defined as the number of distinct configuration types, where a configuration type represented a fundamentally different approach to assembling the cubes (e.g. placing the battery cube in a new location that changed the vehicle’s behavior). *Originality* was defined as configurations that were produced by fewer than 5% of all participants, thereby capturing solutions that were both rare and unconventional.

The participants’ hand movements during the CreaCube task were captured on video. The coding scheme for the CreaCube task is structured around observable actions corresponding to the list of configurations (from F01 to F18).

A configuration is composed of the assembly of the four robotic cubes. Each configuration can be identified in a singular manner, based on the state of the cubes, which has been uniquely named by the coders for analysis purposes. Through video analysis, we were able to code the types of configurations achieved (thus indicating fluency, flexibility, and originality). We also analyzed the duration required to complete the task. It’s important to note that, in this study, the duration of the CreaCube task was not a primary focus.

Procedure

The experiment was conducted individually with each participant in a calm environment. They had no time constraint. The cubes were always arranged in the same way on the playmat and were hidden by a cover. Before the task began, participants sat in front of the covered playmat with the four cubes hidden. There was no free exploration phase prior to the task; once the cover was lifted (see Figure 2). No formal tutorial was provided before the start of the task. We aimed to capture participants’ spontaneous problem-solving and exploratory behaviors, which are central to the assessment of divergent thinking in open-ended creative problem-solving task. Upon revealing the cubes, participants listened to an audio instruction: “You should build an autonomous vehicle that moves from a starting

red point to a finishing black point". This instruction could be replayed upon request, but no additional explanations of cube functionalities were given.

The task was designed to encourage free exploration, enabling children to physically interact with the modules and discover their properties through trial and error. This approach aligns with constructivist views of creativity and problem-solving, particularly in embodied learning environments. Upon successfully completing the task, the cubes were put in initial position and the participant was asked to do the task the second time (A2). The instructions were identical to those given for the first activity, and no specific guidance was provided to the participant regarding whether they needed to solve the activity differently or use the same figure as in the first activity. When the child succeeds, the task is complete.

Analysis

All video recordings of the CreaCube sessions were uploaded to the CreaMaker platform. This platform is a custom-built analytical tool designed to support the coding of creativity-related behaviours in hands-on robotics tasks. It allows researchers to tag and classify configuration sequences, track timing metrics for calculating the scores of fluency (number of total configurations attempted), flexibility (number of distinct configuration types), and originality (configurations produced by < 5% of participants). The platform provides a structured interface for coders to label configurations using a predefined taxonomy (F01–F18). All coding procedures, configuration taxonomies, and task materials can be made available to interested researchers to facilitate replication and further development of robotics-based creativity assessments. We extracted the divergent thinking component scores of fluency, flexibility, and originality from the CreaMaker and analysed the scores using Jamovi (version 2.3.28). We categorised participants' creative behaviours into four profiles, following the framework of Leroy and Romero (2022):

- *Creative*: The participant deliberately created a different configuration in the second attempt (A2) compared to the first (A1) and they successfully completed the task.
- *Conservative*: The participant reused the same configuration from A1 in A2, regardless of performance outcome.
- *Unintentional Creative*: The participant intended to replicate the original solution but failed, inadvertently creating a different successful solution.
- *Unintentional Conservative*: The participant initially attempted a new configuration but reverted to the original one after failing to achieve success.

Results

Firstly, we analyzed the data in terms of fluency, flexibility, originality, and task completion time across two occurrences of the task. Secondly, we explored the creative behaviors exhibited by the participants, categorized into distinct profiles based on their creative intentions and solutions. We examined potential outliers by comparing means and medians and through visual inspection using boxplots. One notably high fluency score was observed in the control group; however, this data point was retained as it reflected valid task behavior. The normality of data

distribution was assessed using the Shapiro – Wilk test. For normally distributed data, the t-test was applied; otherwise, the Mann – Whitney U test was used. Quantitative analyses are complemented by qualitative observations, including notable behavioral patterns specific to children with ADHD. The results are discussed in the context of our hypotheses to shed light on the cognitive processes associated with ADHD.

Quantitative data

Based on the analysis of the videos, we introduce the descriptive statistics (see Table 1, Appendix 1-4) and the results for each of the hypotheses.

H1. Children with ADHD show higher fluency than neurotypical children

In the first occurrence of the task, children with ADHD generated fewer configurations ($M = 4.71$, $SD = 2.69$) than neurotypical children ($M = 9.25$, $SD = 9.88$), but the difference was not significant ($U = 24.5$, $p = 0.727$). In the second occurrence, children with ADHD produced fewer configurations ($M = 3.28$, $SD = 2.56$) than

Table 1. Descriptive statistics showing fluency, flexibility, originality and the time taken for the task for A1 and A2 made in jamovi.

		diversity	mean	median	standard deviation	minimum	maximum
A1 Fluency	ADHD		4.71	5	2.69	1	8
	control		9.25	4.50	9.88	1	27
A1 Flexibility	ADHD		2.00	2	0.82	1	3
	control		2.88	2.00	2.10	1	6
A1 Originality	ADHD		0.43	0	0.79	0	2
	control		1.25	1.00	1.035	0	3
A1 Time	ADHD		138	81	129.1	41	415
	control		159.86	161.50	75.85	64	270
A2 Fluency	ADHD		3.29	2	2.56	1	8
	control		4.25	4.50	2.61	0	7
A2 Flexibility	ADHD		1.71	1	0.95	1	3
	control		1.50	1.00	1.2	0	4
A2 Originality	ADHD		0.71	1	0.76	0	2
	control		0.38	0.00	0.52	0	1
A2 Time	ADHD		201.29	109	255.53	11	678
	control		83.88	85.50	38.3	37	163

neurotypical children ($M = 4.25$, $SD = 2.61$), with no significant difference ($t(13) = -0.721$, $p = 0.484$).

H2. Children with ADHD show higher flexibility than neurotypical children

In the first task, flexibility scores were lower for children with ADHD ($M = 2.00$, $SD = 0.82$) compared to neurotypical peers ($M = 2.87$, $SD = 2.10$), but the difference did not reach statistical significance ($t(13) = -1.032$, $p = 0.321$). In the second task, children with ADHD obtained slightly higher scores ($M = 1.71$, $SD = 0.95$) than neurotypical children ($M = 1.50$, $SD = 1.19$), again without a significant difference ($U = 24.0$, $p = 0.659$).

H3. Children with ADHD show higher originality than neurotypical children

In the first occurrence, originality scores were descriptively lower for children with ADHD ($M = 0.43$, $SD = 0.79$) than for neurotypical children ($M = 1.25$, $SD = 1.04$), although this difference was not statistically significant ($t(13) = -1.709$, $p = 0.111$). In the second task, originality scores were higher for children with ADHD ($M = 0.71$, $SD = 0.76$) than for neurotypical children ($M = 0.38$, $SD = 0.52$), but the difference was not significant ($t(13) = 1.026$, $p = 0.323$).

H4. Children with ADHD spend a higher amount of time to complete both occurrences

In the first task, children with ADHD required 138.00 seconds on average ($SD = 129.09$), while neurotypical children required 159.88 seconds ($SD = 75.85$), with no significant difference ($U = 19.0$, $p = 0.336$). In the second occurrence, children with ADHD required 201.29 seconds on average ($SD = 255.53$) compared to 83.88 seconds ($SD = 38.30$) for neurotypical children, again without a significant difference ($U = 26.0$, $p = 0.867$).

Descriptive and qualitative data

H5. Children with ADHD show a higher rate of non-intentional creative behavior

The observation of the videos allowed us to identify distinct profiles among the children, enabling us to categorize them along two axes: the axis of creative intention (the willingness to recreate the same vehicle in A2 as in A1 or to create something different) and the axis of solution approach (see [Figure 3](#)). Non-intentional creatives included only participants with ADHD (100%), whereas persistent creatives comprised 37.5% ADHD and 62.5% neurotypical participants.

We then assessed a chi-square test of independence to see if there is a significant association between the participant group (ADHD vs. neurotypical) and the creative profile category into four categories (see [Table 2](#)). The chi-square statistic (χ^2) is 5.24 with 3 degrees of freedom, and the p-value is 0.155. Since the p-value is greater than 0.05, we conclude that there is no statistically significant association between the participant group (ADHD vs. neurotypical) and the creative profile categories (see [Figure 4](#)).

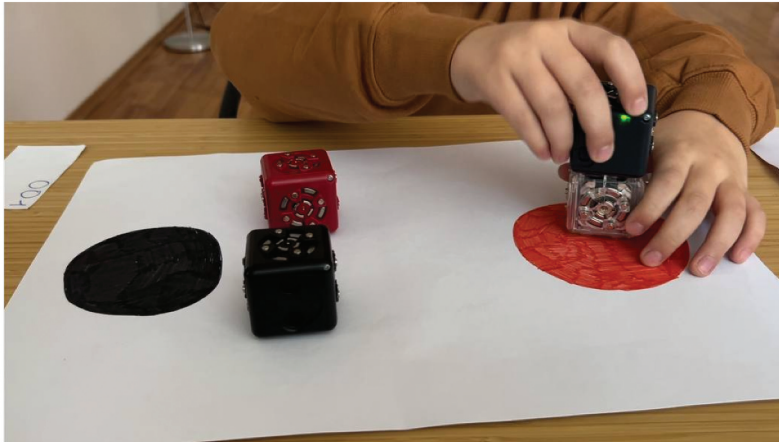


Figure 3. Child assembling the robotic components during the CreaCube task.

Table 2. Contingency table of creative profile categories by participant group (ADHD vs. Neurotypical).

diversity	profile				Total
	Creative	Conservative	Non-intentional Creative	Non-intentional Conservative	
ADHD	2	2	3	0	7
control	5	2	0	1	8
Total	7	4	3	1	15

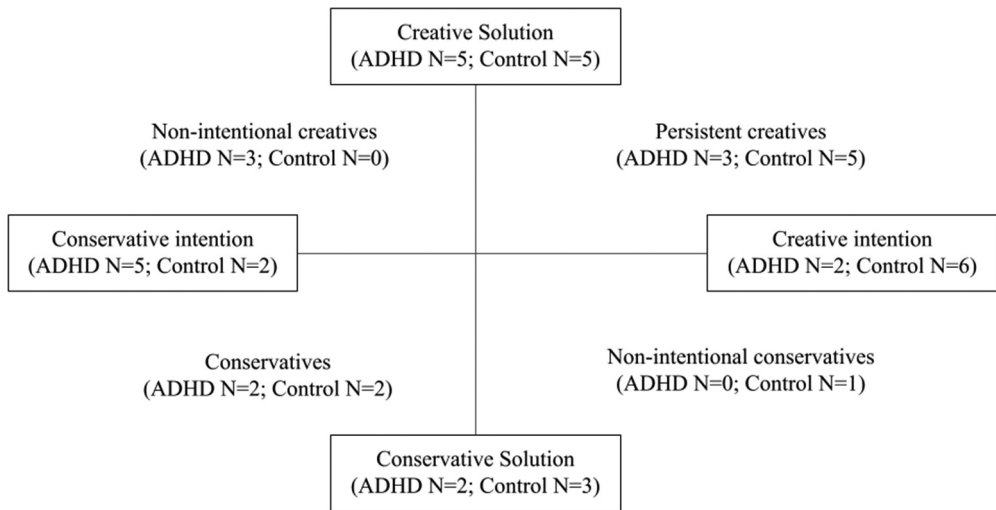


Figure 4. Distribution of the participants' profile considering their creative or conservative intention and their creative or conservative effective solution.

Behavioral observations

In our study, we decided to integrate behavioral observations into the results section due to a notable behavior observed in children with ADHD that was absent in the control group. Specifically, during the task, some children with ADHD used verbal expressions, commenting on their actions. Although the procedure did not require participants to comment on their actions or share their thoughts, children with ADHD exhibited this “think-aloud” technique spontaneously. This behavior provided insights into how they reflected on the task, aiding our analysis. Five out of seven children with ADHD used the think-aloud technique during the task. We quantified the duration of their verbalizations during the video and the nature of their comments (see Table 3).

The majority of the children were primarily commenting on their actions and describing the affordances they noticed. One child frequently asked questions about the task and commented on her perceived lack of skill and logic, expressing doubt about her ability to complete it. Additionally, another child engaged in conversation with the cubes, asking them why they were not moving or moving in the wrong direction.

Discussion

The findings of our study offer nuanced insights into the divergent thinking abilities and behavioral patterns of children with ADHD during a creative problem-solving task using the CreaCube. Despite the lack of significant differences in fluency, flexibility, originality and time taken to complete the task between ADHD and control children, our observations reveal distinct behaviors that underscore the unique cognitive profiles associated with ADHD.

Divergent thinking abilities and task completion

Contrary to our hypotheses, children with ADHD did not demonstrate significantly higher levels of fluency, flexibility, originality or time taken compared to their neurotypical peers. These outcomes highlight the need for further investigation and may underscore the importance of considering task type and assessment modality when evaluating creativity in children with ADHD. The variability in our findings aligns with previous research indicating that the relationship between ADHD and creativity is complex and influenced by various factors such as task type and assessment method (Healey & Rucklidge, 2006; White & Shah, 2006, 2011, 2016). While intelligence was not formally assessed, all

Table 3. Behavioral observations of children with ADHD: thinking out loud technique.

Participant ID	Video duration (in sec)	Verbalization duration (in sec)	% of the child talking	Comments
p1507	107	31	28.97%	Commenting on his actions, emitting hypotheses
p1508	553	59	10.67%	Asking a lot of questions, ego preservation
p1509	109	54	49.54%	Commenting on his actions
p1511	97	40	41.23%	Commenting on his actions
p1512	20	204	9.80%	Talking with cubes

participants were attending mainstream schools and were reported by parents or teachers to be functioning at age-appropriate academic levels. This informal proxy suggests that the sample generally represented average cognitive functioning. In addition to the lack of intelligence testing, we also recognize that age-related cognitive development may have influenced task performance. Older participants may have been exposed to more formal training in logic, mathematics, or technology, which could have helped them approach the problem more systematically or efficiently. These differences, while subtle, may shape divergent thinking outcomes independently of ADHD status. Future research should either control for age more strictly or consider stratified analysis to account for developmental variation in problem-solving abilities.

In the context of fluency, although children with ADHD generated fewer configurations on average, this difference was not statistically significant. Therefore, our findings do not provide evidence to support the hypothesis that ADHD is associated with higher idea generation in this context. Similarly, the results for flexibility and originality did not support our hypotheses, with children with ADHD showing comparable or lower levels than neurotypical peers. The time taken to complete the task had no significant difference between two groups. These outcomes highlight the need for further investigation into how different types of tasks and creative processes interact with ADHD-related cognitive traits.

Non-intentional creative behavior

The descriptive and qualitative analysis of the video observations allowed us to identify distinct profiles among the children. While no statistically significant differences in creative behavior profiles were found between ADHD and neurotypical groups, our qualitative observations suggest that the CreaCube task may be sensitive to subtle, spontaneous behaviors that are not typically captured in traditional, verbal creativity assessments.

Notably, all participants identified as “non-intentional creatives” were in the group with ADHD. This finding, while not significant due to sample size, may hint at underlying cognitive processes worth further exploration. More importantly, these results highlight the feasibility and promise of using a non-verbal, hands-on spatial task to evaluate divergent thinking. This is particularly valuable given the scarcity of spatial and embodied creativity assessments in the literature, and the potential for such tools to reveal new dimensions of cognitive functioning in populations with diverse neurodevelopmental profiles.

The CreaCube task’s format requires physical manipulation, spatial reasoning, and problem-solving without reliance on language. The task’s format may offer a unique window into creativity for children who struggle with conventional, language-heavy testing methods. This aligns with growing interest in embodied cognition and creative expression beyond verbal modalities. Future studies should explore how spatial, manipulative tasks like CreaCube complement or diverge from outcomes on established verbal measures such as the TTCT or AUT. Additionally, the spontaneous use of verbalization (“think-aloud” strategies), observed only in the group with ADHD, may be a productive compensatory strategy for managing cognitive load or enhancing self-regulation. Investigating this phenomenon more systematically could open promising new avenues for both assessment and intervention.

Use of verbalization to help ADHD children

Verbalization has been observed as a spontaneous behavior in children with ADHD during creative problem-solving tasks. In our study, many participants with ADHD engaged in “think-aloud” techniques, wherein they verbalized their thoughts, actions, and hypotheses while working on the CreaCube task. This behavior, while not prompted by the experiment’s protocol, provided valuable insights into their reflective strategies. The think-aloud technique serves several functions for children with ADHD. Firstly, it aids in organizing their thoughts and actions, which can be particularly beneficial given the executive function deficits often associated with ADHD (Barkley, 2014). By verbalizing their steps, these children can maintain focus on the task and self-regulate their behavior more effectively. Secondly, verbalization can serve as a tool for externalizing their internal monologue, making abstract thoughts more concrete and easier to manage.

Research supports the benefits of verbalization in enhancing problem-solving and learning in children with ADHD. For instance, a study by Corkum et al. (2008) found that children with ADHD produced more task-relevant external private speech than their typically developing peers during problem-solving tasks. This external verbalization helps them regulate their attention and control their behavior, which is particularly useful given their deficits in inhibition and self-regulation. Similarly, our findings showed that spontaneous verbalizations reflected the children’s engagement and active problem-solving approach. Some children used verbalization to hypothesize about whether a specific configuration would work, ask questions about the task, or express frustration and persistence. These verbalizations not only reflect their cognitive engagement but also provide educators and therapists with a window into the child’s thought process, enabling more tailored support.

Limits of our study and methodology

There are several limitations that restrict the generalizability of our results. Firstly, our study involved only a small sample of neurotypicals and children with ADHD, limiting the ability to generalize findings to a broader population. Secondly, we did not categorize children according to their specific ADHD symptoms. Additional tests could have been conducted to determine whether children were predominantly hyperactive, inattentive, or exhibited a combination of both. This categorization could have provided deeper insights into the variations within the group with ADHD. Thirdly, intelligence was not assessed, which could have served as an exclusion criterion. Conducting IQ assessments or using WISC-III tests could have helped explain the performance of certain outliers, such as the one child whose results differed significantly from others. A higher IQ might serve as a protective factor for children with executive functioning deficits, allowing them to perform better on tasks despite their challenges. Additionally, incorporating other tests to assess creativity, such as the TTCT or AUT, would have provided a basis for comparing our findings with those from the CreaCube task, enhancing the robustness of our conclusions.

Future research and implications

Future research should aim to include larger and more diverse samples, encompassing children, adolescents, young adults, and adults, to comprehensively explore the relationship between creativity and ADHD across different age groups. By expanding the age range of participants, we can investigate whether the creative strengths associated with ADHD evolve or diminish over time. Additionally, it would be interesting to examine the developmental trajectory of creativity in individuals with ADHD and it can provide insights into how these cognitive traits may change with age. Stolte et al. (2022) found that there is a relationship between specific ADHD symptoms and divergent thinking. They revealed that inattention symptoms were positively correlated with all three divergent thinking measures, whereas hyperactivity/impulsivity symptoms were linked to fluency and flexibility. It would be interesting to analyze that using the CreaCube task.

When assessing creativity in individuals with ADHD, employing a variety of tests is essential to capture the multifaceted nature of creativity. Utilizing diverse assessment tools, such as the TTCT, the AUT, and innovative methods like the CreaCube task, can reveal different profiles and dimensions of creativity in populations with ADHD. This approach will allow researchers to identify distinct cognitive strengths and weaknesses, leading to a more nuanced understanding of creativity in ADHD. Furthermore, integrating qualitative methods, such as video observations and think-aloud protocols, can provide deeper insights into the creative processes and behaviors of individuals with ADHD. These methods can complement quantitative assessments and offer a more comprehensive view of how ADHD influences creativity.

Conclusion

This study serves as an exploratory investigation into the use of a novel, manipulative robotics-based task named CreaCube to assess creativity-related behaviors in children with and without ADHD. Although no statistically significant differences were found between the groups on standard measures of divergent thinking (fluency, flexibility, originality, and time), the task revealed interesting qualitative patterns, particularly spontaneous verbalization and non-intentional creative behavior, that may reflect unique cognitive strategies among children with ADHD. These findings suggest that non-verbal, embodied tasks such as CreaCube may offer a valuable complement to traditional creativity assessments, particularly for neurodiverse populations. Future research should further evaluate the reliability and discriminative power of such tools using larger and more demographically diverse samples, and include cognitive and academic functioning assessments to contextualize performance outcomes.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the Agence Nationale de la Recherche (ANR) in France [grant number ANR-18-CE38-0001] <https://anr.fr/Project-ANR-18-CE38-0001>.

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Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical committee of Université Côté d'Azur (Comité d'Ethique pour les Recherches Non Interventionnelles, CERNI, 2019–6).

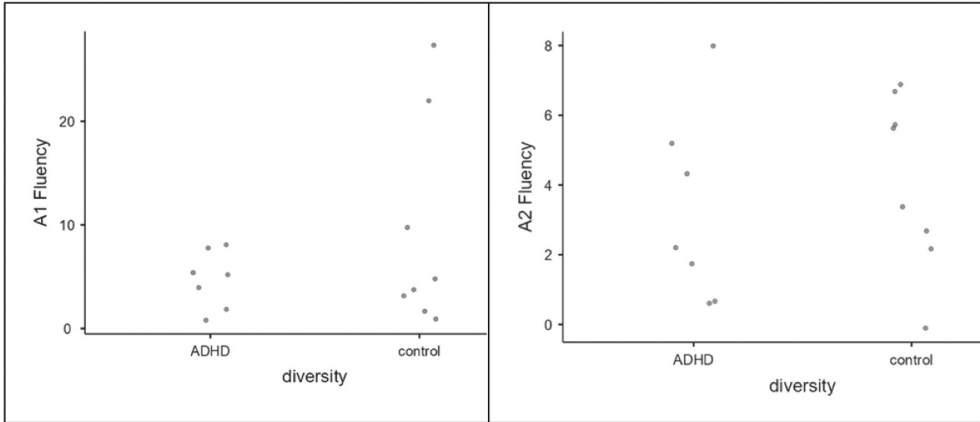
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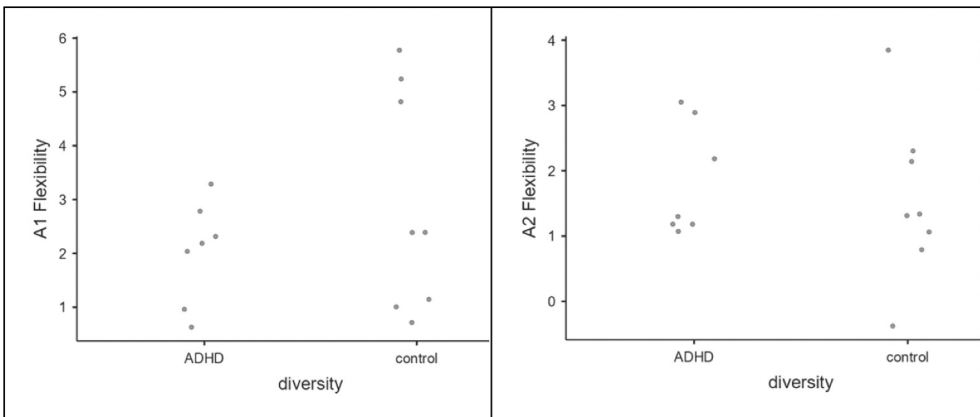
Appendices

Appendix A



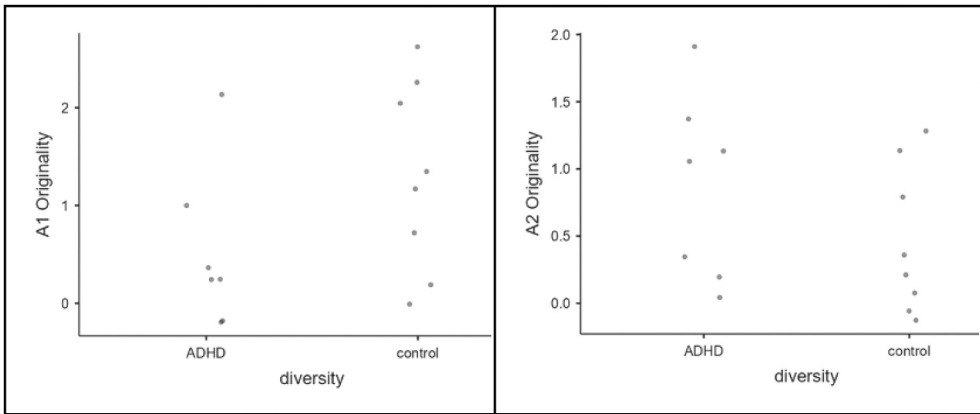
Graphic distribution of fluency scores in first and second occurrences of the task in ADHD and control groups.

Appendix B



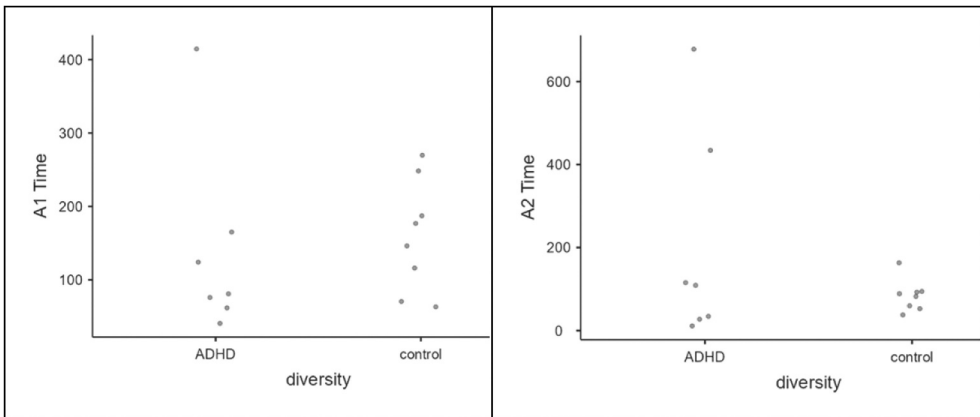
Graphic distribution of flexibility scores in first and second occurrences of the task in ADHD and control groups.

Appendix C



Graphic distribution of originality scores in first and second occurrences of the task in ADHD and control groups.

Appendix D



Graphic distribution of time taken in first and second occurrences of the task in ADHD and control groups.