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Visuospatial attention and intelligence in children with ADHD-hyperactive type

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Abstract

Aim: Attention is a core cognitive function that supports higher-order processes such as reasoning, problem solving, and intelligence. In children with attention deficit hyperactivity disorder (ADHD), particularly the hyperactive subtype, impairments in attentional control may interfere with the development and expression of cognitive abilities. This study examined the relationship between visuospatial attention and both verbal and nonverbal intelligence in children with ADHD-hyperactive type (ADHD-H).

Methods: A sample of 65 children with ADHD-H and 73 typically developing controls (aged 8–10 years) completed three tasks: the Benton Visual Form Discrimination Test (VFDT), assessing complex visuospatial attention; the Raven's Colored Progressive Matrices (RCPMs), measuring nonverbal fluid intelligence; and the Verbal Abstraction Test (Comprehension and Verbal Absurdities subtests), assessing verbal reasoning. Independent-samples *t*-tests and mixed-design ANOVAs were conducted to compare group performance and examine within-task variability.

Results: Children with ADHD-H performed significantly worse than controls on both the VFDT and the RCPMs total scores. Qualitative analysis revealed a marked decline in performance across VFDT item sets, more frequent peripheral errors in later trials. Group differences in RCPMs emerged in gestalt and analogy subcomponents but not in perceptual similarity items. Conversely, verbal abstraction scores did not differ significantly between groups.

Conclusions: Findings suggest that attentional deficits, rather than global intellectual impairment, primarily account for lower nonverbal reasoning performance in children with ADHD-H. Verbal reasoning abilities appear relatively preserved. These results underscore the need for differential diagnostic assessment and targeted interventions to strengthen visuospatial attention and cognitive control in ADHD-H.

Keywords

ADHD-hyperactive type, visuospatial attention, fluid intelligence, verbal abstraction, cognitive control, children

Introduction

The relationship between attention and intelligence is a central issue in cognitive neuroscience, as both domains rely on overlapping neural substrates and cognitive mechanisms [1–4]. Attention is a basic condition for all higher functioning and for any kind of intellectual activity. The ability to selectively focus on relevant stimuli, while simultaneously inhibiting distractors, underlies the overall process, from primary stimulus encoding to higher-order cognitive processing, especially if we consider that the human capacity to process information is rather limited compared to the very large amount of internal and external stimuli [5–7].

Visuospatial attention allows for the selective processing of spatially organized visual information, the extraction of rules and patterns, and the concentration on specific visual stimuli while suppressing irrelevant details [8].

Within the Cattell-Horn-Carroll theory of intelligence, visuospatial attention plays a significant role in problem-solving and fluid intelligence tasks by enhancing visual processing, supporting visual working memory, and maintaining attentional focus. Similarly, the process overlap model posits that attentional control, including visuospatial attention, is a core mechanism underlying performance on intelligence tasks [9, 10].

Accordingly, stronger visuospatial attention skills predict better outcomes in problem solving and nonverbal reasoning. Eye-tracking studies show that children with higher intelligence scores allocate attention more strategically, concentrating on relevant features rather than scanning randomly [11–13].

Developmental research further suggests that these associations are particularly strong during childhood, when attentional systems are still maturing and exert a strong influence on reasoning ability [14–16].

At the neuroanatomical level, both visuospatial attention and fluid intelligence depend on frontoparietal networks subserving executive control, working memory, and abstract reasoning, particularly the posterior parietal cortex, dorsolateral prefrontal cortex, and inferior frontal gyrus [17, 18].

Prefrontal structures play a pivotal role by integrating attentional processes with higher-level executive functions. Because attention pervades virtually all aspects of cognition, deficits in attentional development can compromise encoding, storage, retrieval, reasoning, and planning [1, 19–22].

Consequently, low academic performance may stem from difficulties in sustaining attention or maintaining working memory [23–28].

Nevertheless, poor scores on intelligence tests are often considered exclusively as evidence of global cognitive impairment. Raven's Colored Progressive Matrices (RCPMs), for instance, are widely used as a measure of nonverbal fluid intelligence and are evaluated as a single measure of general intelligence. However, several studies have shown that performance depends on distinct cognitive abilities, such as analytic reasoning, analogical reasoning, and figural processing, and recruits different neural substrates, including bilateral frontal and left temporo-parieto-occipital regions. More recent neuropsychological research has identified three qualitative item clusters: (i) items requiring complex analytical and gestalt reasoning; (ii) items requiring abstract analogical reasoning; and (iii) items requiring simple perceptual completion based primarily on visuospatial attention [29–32]. This evidence indicates that similar overall RCPMs scores may result from different underlying cognitive strategies, including attentional mechanisms. Attention deficit hyperactivity disorder (ADHD) is a neurodevelopmental condition characterized by impairments in attentional control, manifesting as inattention, hyperactivity, impulsivity, or their combination [33]. Attention deficits, particularly difficulties in sustaining and shifting spatial attention, are more prominent in the inattentive subtype of ADHD (ADHD-I), while deficits in impulse control during visuospatial tasks are more strongly associated with the hyperactive subtype (ADHD-H). Such deficits affect learning, memory, and executive functioning, with broad consequences for academic achievement and social adjustment [34–39]. The present study investigates visuospatial attention and both verbal and nonverbal intelligence in children with the hyperactive subtype of ADHD. We hypothesized that poor performance on tasks of fluid intelligence in this group would primarily reflect deficits in attentional control rather than global intellectual impairment. Specifically, compared to typically developing peers, children with ADHD-H were expected to perform worse on a visuospatial attention task [the Visual Form Discrimination Test (VFDT)] and on RCPMs, which is heavily dependent on visuospatial processing, but not on a verbal abstraction task. This study thus aims to contribute to a more differential assessment of cognitive abilities in ADHD, clarifying the extent to which attentional deficits influence measures of intelligence. Such differentiation is critical in both clinical and educational settings, as it allows practitioners to distinguish poor attentional performance from poor general intelligence and to address each domain appropriately in rehabilitation.

Materials and methods

Participants

The study included a total sample of 138 children recruited from various schools in Sicily. The clinical group consisted of 65 children with a diagnosis of ADHD-H (12 girls; mean age = 9.1 years, SD = 0.35; age range: 8–10 years). Diagnosis was established through a comprehensive clinical assessment conducted by a licensed clinical specialist with expertise in neurodevelopmental disorders. Behavioral symptoms were assessed using standardized rating scales completed independently by parents and teachers, providing information on symptom presence and severity across settings. These data were integrated with a direct clinical interview and behavioral observation of the child. Final diagnostic classification and subtype determination (ADHD-H) were made by the clinician in accordance with DSM-5 criteria, considering symptom severity, cross-setting consistency, and clinical judgment. Medication history was systematically collected as part of the clinical assessment. All children included in the ADHD-H group were either medication-naïve or were assessed following an appropriate washout period. No participant was receiving stimulant or other psychotropic medication at the time of neuropsychological testing, to avoid potential confounding effects of pharmacological treatment on attentional and cognitive performance. The control group comprised 73 children (14 girls; mean age = 8.7 years, SD = 0.81) drawn from the same schools and classrooms as the ADHD-H group. These children had no history of neurological or psychiatric disorders, learning disabilities, or developmental delays.

Procedures and measures

Socioeconomic background information was collected for all participants, including parental education level and occupational status. Socioeconomic status (SES) was operationalized according to national ministerial classifications, based on parents' highest educational attainment and occupational category. These variables were examined to ensure comparability between the ADHD-H and control groups.

The Benton VFDT was administered as a measure of **complex visual attention** [40–42]. The test comprises 16 multiple-choice items in a matching-to-sample format. In each trial, participants analyzed three target geometric figures and identified, among four sets of three figures, the one matching the target. Distractors involved spatial rotations or distortions. The test was administered individually without time limits. Scoring followed Benton's procedure: 2 points for a correct answer, 1 point for a peripheral error, and 0 for other errors (maximum score = 32). Total response time was also recorded.

The **nonverbal fluid intelligence** was assessed with the RCPMs [43, 44], administered individually and without time limits. Each correct answer received one point (maximum = 36). Total score and response time were analyzed.

Verbal abstraction was measured with two subtests from the Italian adaptation of the Stanford-Binet Intelligence Scale, Form L-M [45]: Comprehension (6 items, assessing reasoning based on social norms and common sense) and Verbal Absurdities (9 items, assessing the detection of logical inconsistencies). Both were administered orally and scored dichotomously (pass/fail). The combined maximum score was 15, used as an index of verbal abstraction.

Statistical analysis

Data were analyzed using *Jamovi* (version 2.5.6.0). Descriptive statistics (means and SDs) were computed for all measures.

Given the hypothesis-driven nature of the analyses, uncorrected p values were reported. However, to control for potential inflation of Type I error, a false discovery rate correction (Benjamini-Hochberg) was applied to the main between-group comparisons, confirming the robustness of the results.

Group differences between children with ADHD-H and typically developing controls were examined using independent-samples t-tests, while within-task performance variations were examined using repeated-measures or mixed-design ANOVAs, as appropriate. Effect sizes were reported as Cohen's d for between-group comparisons and partial η^2 for ANOVA effects.

For the VFDT, performance was analyzed across two task halves (Items 1–8 vs. 9–16) to evaluate performance continuity. Specifically, this comparison was conducted using a repeated-measures ANOVA. Additional repeated-measures ANOVAs examined the influence of stimulus position on accuracy, considering both horizontal (left-right) and vertical (top-bottom) response locations.

RCPM performance was analyzed using independent-samples t-tests for the total score and for three cognitive components, *similarity*, *gestalt reasoning*, and *analogy,* based on previous factor-analytic models. Finally, the Verbal Abstraction Test was evaluated using independent-samples t-tests for both total and subtest (Comprehension, Verbal Absurdities) scores. Statistical significance was set at $p < 0.05$ (two-tailed).

Results

No significant differences emerged between groups with respect to socioeconomic status or parental education levels (all p values > 0.05) (Table 1).

Table 1. Demographic and socioeconomic characteristics of the ADHD-H and control groups.

Variables	Controls (n = 73)	ADHD-H (n = 65)	p
Age (years), mean ± SD	8.7 ± 0.81	9.1 ± 0.35	0.62
Sex (% male)	80.82%	81.54%	0.74
Parental education (years), mean ± SD	13.8 ± 2.6	13.5 ± 2.8	0.48
Socioeconomic status (SES), mean ± SD	45.2 ± 8.1	44.6 ± 8.4	0.67

No significant differences were observed between groups for demographic or socioeconomic variables (p > 0.05). ADHD-H: attention deficit hyperactivity disorder-hyperactive type.

Group comparisons are summarized in Table 2. Children in the control group performed significantly better than children with ADHD-H on both visuospatial and nonverbal reasoning tasks. Specifically, controls obtained significantly higher scores than children with ADHD-H on the VFDT (t_{136} = 7.97, p < 0.001, d = 1.35, 95% CI [0.98, 1.72]) and on the RCPMs (t_{136} = 4.56, p < 0.001, d = 1.69, 95% CI [1.30, 2.08]). These large effect sizes indicate substantial group differences in visuospatial attention and fluid intelligence. No significant group difference was observed for verbal abstraction abilities (t_{136} = 1.59, p = 0.116, d = 0.26, 95% CI [−0.08, 0.60]), suggesting that verbal reasoning remains relatively preserved in children with ADHD-H.

To examine this pattern qualitatively, the VFDT was divided into two halves (Items 1–8 and Items 9–16). The error distribution in the VFDT revealed a clear trend in performance across the test sequence. A repeated-measures ANOVA with *Set* (first half vs. second half) as the within-subject factor and *Group*

Table 2. Group comparisons on visuospatial attention, fluid intelligence, and verbal abstraction measures.

Measure	Controls (mean ± SD)	ADHD-H (mean ± SD)	t (df = 136)	*p*	Cohen's *d*	95% CI
VFDT total score	27.02 ± 2.20	23.90 ± 2.40	7.97	< 0.001	1.35	[0.98, 1.72]
RCPMs total score	27.58 ± 1.81	23.02 ± 3.31	4.56	< 0.001	1.69	[1.30, 2.08]
Verbal Abstraction Total score	11.32 ± 0.11	10.91 ± 2.25	1.59	0.116	0.26	[−0.08, 0.60]

VFDT: Visual Form Discrimination Test; RCPMs: Raven's Colored Progressive Matrices; ADHD-H: attention deficit hyperactivity disorder-hyperactive type.

(ADHD vs. control) as the between-subject factor revealed a significant main effect of *Set* [$F_{(1,136)} = 94.6$, $p < 0.000001$], indicating that performance declined significantly in the second half of the test. The number of correct responses was significantly higher in the first half compared to the second ($p < 0.000001$). A descriptive trend suggested a greater performance decline across task halves in the ADHD-H group compared to controls, suggesting that attentional control and sustained focus deteriorate as the visuospatial task progresses over time in children with ADHD-H. Peripheral errors were also analyzed across the two sets and showed significant differences in all groups, being more frequent in the second half sets.

Furthermore, since correct responses in the test are evenly distributed across the four quadrants (4 correct responses for each quadrant: above, below, right, left), a qualitative analysis was conducted to examine whether the spatial position of the correct alternatives on the response sheet influenced performance. When comparing items with correct answers positioned on the left (options 1 and 3) vs. the right side (options 2 and 4), a significant main effect of position emerged [$F_{(1,136)} = 46.4$, $p < 0.000001$]. Correct responses were significantly more frequent when the correct alternative appeared on the right side of the page. Similarly, when the distribution of correct responses was analyzed according to their vertical position, top (options 1 and 2) vs. bottom (options 3 and 4), the main effect of *Side* was not significant [$F_{(1,136)} = 0.04$, $p = 0.85$]. A non-significant descriptive trend indicated a higher number of correct responses for top-positioned alternatives in the ADHD-H group.

Table 3 reports the mean RCPM scores for both groups, including the total score (overall number of correct responses out of 36) and the three cognitive components identified in previous factor-analytic studies: *similarity*, *gestalt reasoning*, and *analogy*. Children in the control group obtained higher and more homogeneous scores (with smaller standard deviations) than those with ADHD-H across all parameters. However, the difference between groups on the **similarity** factor (11 items requiring perceptual matching by visual similarity) was not statistically significant (Controls: mean =10.75 ± 0.48; ADHD-H: mean = 10.13 ± 2.87; $p > 0.05$).

Table 3. Mean RCPM scores (total and by cognitive factor) in the ADHD-H and control group.

RCPMs factor	Controls (mean ± SD)	ADHD-H (mean ± SD)	t (df = 136)	*p*
Similarity (11 items)	10.75 ± 0.48	10.13 ± 2.87	1.47	n.s.
Gestalt reasoning (15 items)	12.98 ± 2.78	10.89 ± 3.95	2.09	< 0.05
Analogy (10 items)	4.56 ± 1.54	2.10 ± 3.98	2.46	< 0.05
Total score (36 items)	27.58 ± 1.81	23.02 ± 3.31	4.56	< 0.001

RCPMs: Raven's Colored Progressive Matrices; n.s.: non-significant; ADHD-H: attention deficit hyperactivity disorder-hyperactive type.

In contrast, significant differences emerged in the remaining components. On the **gestalt reasoning** factor (15 items requiring complex integration of visual information), the control group outperformed the ADHD-H group (mean = 12.98 ± 2.78 vs. 10.89 ± 3.95; $t_{136} = 2.09$, $p < 0.05$). A similar pattern was found for the **analogy** factor (10 items requiring abstract reasoning by analogy), where the difference was even larger (mean = 4.56 ± 1.54 vs. 2.10 ± 3.98; $t_{136} = 2.46$, $p < 0.05$).

Finally, the difference in total RCPMs score was highly significant, with the control group obtaining markedly higher scores (mean = 27.58 ± 1.81) than the ADHD-H group (mean = 23.02 ± 3.31; t_{136} = 4.56, $p < 0.001$).

Table 4 presents the mean scores of the two groups on the Verbal Abstraction Test. Overall, children in the control group obtained slightly higher mean scores than those with ADHD-H, both in the total score and in the two individual subtests. Specifically, control participants performed marginally better on the Comprehension subtest (mean = 4.65 ± 0.25 vs. 4.32 ± 2.31) and on the Verbal Absurdities subtest (mean = 7.40 ± 0.45 vs. 7.12 ± 2.23). Similarly, the total score tended to be higher in the control group (mean = 11.32 ± 0.11) compared to the ADHD-H group (mean = 10.91 ± 2.25).

Table 4. Mean verbal abstraction scores in the ADHD-H and control group (non-significant differences).

Verbal abstraction measure	Controls (mean ± SD)	ADHD-H (mean ± SD)	Mean difference	t (df = 136)	*p*
Comprehension (6 items)	4.65 ± 0.25	4.32 ± 2.31	0.33	1.15	n.s.
Verbal absurdities (9 items)	7.40 ± 0.45	7.12 ± 2.23	0.28	0.99	n.s.
Total (15 items)	11.32 ± 0.11	10.91 ± 2.25	0.41	1.47	n.s.

n.s.: non-significant; ADHD-H: attention deficit hyperactivity disorder-hyperactive type. No statistically significant differences were found between groups ($p > 0.05$).

However, none of these differences reached statistical significance ($p > 0.05$), indicating that verbal abstraction abilities were largely comparable between the two groups.

Discussion

The present study investigated visuospatial attention, nonverbal fluid intelligence, and verbal abstraction in children with ADHD-H, compared with typically developing peers. The results provide evidence that attentional control plays a fundamental role in nonverbal reasoning performance and may underlie poorer performance on nonverbal reasoning tasks in ADHD-H, while verbal abstraction abilities remain relatively intact.

Children with ADHD-H scored significantly lower than controls on the VFDT, with large effect sizes, indicating a pronounced deficit in visuospatial attention during discrimination of complex visual forms. The analysis of both central and peripheral figures was significantly impaired, with a higher number of errors, suggesting difficulties in selectively exploring and integrating visuospatial exploration, flexible visual search strategies, and sustained attentional maintenance to match target figures with one of several alternatives.

Overall, the performance pattern is consistent with inefficient visuospatial scanning and reduced attentional control during complex visual processing.

Furthermore, in the second half of the VFDT, the ADHD-H group showed a greater decline in performance compared to the first half, a pattern that was more evident at a descriptive level than in the control group. This finding suggests increasing difficulty in maintaining visuospatial attention and attentional control as task demands persist over time. Importantly, this effect cannot be attributed to differences in item difficulty, since the VFDT does not involve a progressive increase in complexity [42].

Moreover, qualitative analysis of the distribution of correct responses across spatial quadrants revealed descriptive spatial biases in attentional deployment. Children with ADHD-H identified right-sided targets more accurately than left-sided ones, and a non-significant trend indicated better performance for upper compared to lower spatial positions. These findings suggest asymmetries in visuospatial exploration, consistent with reduced sustained and selective visual processing. Such rightward biases have been previously reported in visual or visuomotor tasks in ADHD-H and may reflect altered attentional allocation rather than focal neglect [46, 47].

A large body of literature has demonstrated the functional dominance of the right hemisphere for sustained and spatial attention, impulse control, and visuospatial integration. Furthermore, several studies have highlighted similarities between ADHD-H and attentional disturbance observed in patients with acquired right hemisphere dysfunction [48–50]. Within this framework, the spatial biases observed in the present study may be interpreted as reflecting altered efficiency within right-lateralized attentional networks, rather than focal structural impairment [48–51]. Repetitive response patterns were also observed in the ADHD-H group, consistent with reduced inhibitory control and cognitive flexibility, in line with core behavioral characteristics of ADHD [34]. Similar executive dysfunctions involving inhibition, set-shifting, and working memory have also been reported in preschool children with Global Developmental Delay, suggesting that early impairments in executive control may represent a transdiagnostic vulnerability factor across neurodevelopmental conditions [52].

From a neurofunctional perspective, these findings are compatible with models proposing that attentional deficits in ADHD arise from delayed or inefficient functioning within the frontoparietal attention network. Both the prefrontal and posterior parietal cortices play a crucial role in top-down modulation of visual attention and in maintaining goal-directed focus during complex visuospatial processing [53].

Structural and functional neuroimaging studies in individuals with ADHD have identified alterations in multiple brain regions, including the dorsolateral and ventrolateral prefrontal cortices and fronto-striatal circuits [54–57]. These findings provide a neurobiological framework within which attentional inefficiencies observed behaviorally may be understood, although direct neural inferences cannot be drawn from the present data.

In line with our hypothesis, children with ADHD-H performed significantly worse than controls on the RCPMs total score and on the two components requiring higher-order visuospatial integration and abstraction, such as gestalt reasoning and analogy processes. Conversely, the similarity component, involving simpler perceptual matching, did not differ significantly between groups. This dissociation suggests that basic perceptual processes are relatively preserved in ADHD-H, whereas impairments emerge when attentional control and integrative reasoning are required. This pattern reinforces the view that deficits in attentional control and visuospatial processing constrain performance on fluid intelligence tasks that depend on sustained manipulation and integration of visual information [58]. Accordingly, lower performance on nonverbal intelligence measures in ADHD-H should not be interpreted as evidence of reduced general intelligence, but rather as secondary to attentional dysregulation.

Consistent with this interpretation, no significant differences emerged between groups on the Verbal Abstraction Test. The comparable performance of children with ADHD-H and controls suggests that verbal reasoning and semantic abstraction abilities are relatively preserved. This dissociation between verbal and visuospatial modalities supports the view that cognitive deficits in ADHD-H are domain-specific rather than global, with greater vulnerability in tasks requiring visuospatial exploration and sustained attentional engagement.

Our results may have significant diagnostic and rehabilitative implications. First, they suggest that clinicians, educators, and intervention programs should be careful when interpreting low scores on fluid intelligence tasks in children with ADHD. Poor performance on visually mediated nonverbal tasks such as the RCPMs may reflect attentional instability rather than intellectual delay. Misinterpreting such scores as indicators of low general intelligence could lead to diagnostic inaccuracies and inappropriate educational strategies.

Second, the findings emphasize the need for targeted neurocognitive training aimed at improving visuospatial attention, impulse control, and strategic visual exploration. Such interventions could not only enhance attentional efficiency but also indirectly strengthen reasoning and learning capacities. Given the strong relationship between attention, executive functioning, and academic success, programs fostering attentional control could yield broad developmental benefits.

Limitations and future directions

Several limitations warrant mention. First, our sample, although reasonably sized, is cross-sectional; thus, we cannot draw causal inferences about how attentional development influences reasoning growth over time. Longitudinal studies would clarify whether attention deficits precede or co-develop with reasoning impairments.

Second, our assessment of spatial-position effects was exploratory and did not include eye-tracking data; future research combining eye-movements or gaze metrics could more precisely characterize attentional bias and focal deployment.

Third, although we used standardized tests, cognitive performance can be influenced by motivational, fatigue, or practice effects, particularly in children with ADHD. Administering counterbalanced orders or breaks might help mitigate these effects.

Finally, while we examined specific subcomponents of the RCPMs, the test itself represents a limited snapshot of fluid intelligence. Broader batteries, including matrices, planning, and novel problem-solving tasks, would strengthen generalizability.

Conclusion

Our results lend empirical support to theories positing that attention is a foundational process for higher cognitive operations. In ADHD, deficits in sustained visuospatial attention may cascade into poorer performance in fluid reasoning tasks that place high demands on working memory, inhibition, and mental manipulation. These findings align with previous literature showing robust impairments in visuospatial working memory in ADHD. Moreover, emerging models of ADHD emphasize that impairments in neural connectivity, particularly within frontoparietal networks, may underlie attention instability and inefficient processing of spatial information.

In summary, our findings support a model in which visuospatial attentional control is a key factor in performance on nonverbal reasoning tasks in children with ADHD-H. Deficits in sustained and spatially biased attention may lead to poor performance, rather than (or in addition to) a pure reasoning deficit. The preservation of verbal abstraction skills underscores the domain-specific nature of the cognitive impairment in ADHD-H. Future longitudinal studies are needed to clarify the developmental trajectories of these processes and evaluate the effectiveness of attentional training in enhancing cognitive and academic outcomes in ADHD-H.

Abbreviations

ADHD: attention deficit hyperactivity disorder

ADHD-H: attention deficit hyperactivity disorder-hyperactive type

RCPMs: Raven’s Colored Progressive Matrices

VFDT: Visual Form Discrimination Test

Declarations

Author contributions

DS: Validation, Investigation, Formal analysis, Visualization, Writing—original draft, Writing—review & editing. PS: Conceptualization, Investigation, Writing—original draft, Writing—review & editing. MR: Writing—review & editing, Supervision. All authors read and approved the submitted version.

Conflicts of interest

Prof. Michele Roccella, who is the Editorial Board Member and Guest Editor of *Exploration of Neuroprotective Therapy*, had no involvement in the decision-making or the review process of this interest. The other authors declare no conflicts of interest.

Ethical approval

The study was approved by the Bioethics Committee of the University of Palermo (n.73/2022) and conducted in accordance with the ethical principles of the Declaration of Helsinki.

Consent to participate

Informed consent to participate in the study was obtained from all participants' parents.

Consent to publication

Informed consent for the publication of anonymized data was obtained from all participants' parents.

Availability of data and materials

The datasets that support the findings of this study are available from the corresponding author upon reasonable request.

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