Attention Deficit/Hyperactivity Disorder and Motor Planning Difficulties: A Confirmatory Study on the Overlap Between Neurodevelopmental Disorders

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Abstracts: Attention deficit/hyperactivity disorder (ADHD) and developmental coordination disorder (DCD) represent two frequent neurodevelopmental disorders, which may be comorbid or have common characteristics with each other. The aim of the present study was to explore the presence of DCD or motor planning difficulties in children with behavioral disorders and/or ADHD, as already stated in the literature. Motor abilities were assessed in a sample of children which underwent a comprehensive neuropsychological evaluation. A total of 43 children were included in the study and were subdivided in three groups: those with ADHD and DCD, those with DCD, and those with ADHD but also presenting motor-praxic difficulties. The first group obtained clinical scores at the considered tests, with worse performances in the balance area; in the second and third groups lower scores were observed in the manual dexterity and balance, with more homogeneous profiles. Overall, 27.3% of ADHD subjects received a diagnosis of DCD as well, whereas 31.8% showed documented motor-praxic difficulties. Our results confirmed an increased prevalence of DCD or general motor difficulties in children with ADHD compared to the general population. Further research should investigate whether a poorer motor performance assessed by standardized tests could be either due to a comorbid neurodevelopmental condition or a direct consequence of the pivotal symptomatology of the disorder.

Keywords: Attention deficit/hyperactivity disorder, Developmental coordination disorder, Motor skills, Neurodevelopmental disorders.

INTRODUCTION

According to the DSM-5-TR [1], the Attention Deficit / Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder characterized by hyperactivity, impulsiveness, and/or inattention, with a typical onset before 12 years of age. This condition has been described as the most common behavioral disorder in children [2], with a prevalence of approximatively 5% in children and 2.5% in adults, usually more commonly observed in males rather than females [3]. The two core symptoms (inattention and hyperactivity/impulsiveness) may be both present, but it is not unusual the expression of only one of them [2]. However, notwithstanding the clinical presentation, these symptoms lead to compromission of global functioning and development [4, 5], with difficulties to follow orders and instructions, as well as problems in self-control and respecting rules. Regarding the evolution of this disorder throughout the years, it evolves differently according to several variables, such as the quality of relationships with and between family members, the child's acceptance in the school context, the general cognitive profile and the presence of any other disorders [6]. The disorder is most commonly identified during the school years, when inattention becomes more prominent and disabling [6]. Furthermore, impulsiveness and low tolerance for reproaches may generate negative effects in the interaction with the parent, triggering a vicious cycle that can lead to an accentuation of the symptomatology [6]. A diagnosis requires a recollection of information from different life contexts: parents, teachers, other educators, in order to explore all the aspects of the child's behavior and social functioning. In addition, a clinical observation is required in order to evaluate the attention abilities, activity planning, self-control, and inhibition of automatic responses, but also cognitive abilities, school learning, and the presence of language disorders.

On the other hand, the Developmental Coordination Disorder (DCD) represents one of the most common movement disorders in developmental age [7-9], and it is characterized by a delay in the development of motor skills or difficulty in coordinating movements, which often leads to difficulties in carrying out daily activities [10]. The prevalence is 5-6% in children between 5 and 11 years and is more common in boys than girls, with a ratio ranging from 2:1 to 7:1 [11-13]. The comorbid presence of DCD and other developmental disorders or learning difficulties, such as ADHD, Specific Language Disorders, and Specific Learning Disorders is typical [14-20]. The co-occurrence of other disorders has an

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additional impact on the clinical picture, course and outcome. DCD is predominantly characterized by impaired sensorimotor coordination, which involves the activation, appropriate sequential organization, timing regulation, and modulation of the activity of many muscle groups; it consists in the ability to perform fast, appropriate and economical movements and results from the interaction of many systems involving both the nervous system and the neuromuscular and osteo-tendon structures [10]. DCD also has several signs such as marked delays in achieving basic movement patterns, clumsiness, poor balance, and poor postural control, bimanual coordination difficulties, difficulty writing by hand, difficulties in motor learning, strategic planning, timing and sequence of movement, difficulty performing activities that require constant change in body position or difficulty reacting to changes in the environment, and visual-spatial information processing deficits. Individuals with DCD also have difficulty with visual tasks that do not include motor components, such as length discrimination, judgment of magnitude, and locating the position of objects in space. Furthermore, the relationship between perceptive skills and motor skills was analyzed [21], and it was observed how visual-perceptive skills and motor control strongly interact with one other, although visual-perceptive difficulties may be absent or in any case not very decisive in the genesis of the failure of motor or visual-motor activities in individuals with DCD.

The course of the disorder is variable but stable at least up to 1 year of follow-up. Long-term improvements may occur, but problems with movement coordination persist into adolescence in about 50-70% of children [22-24]. DCD cannot be diagnosed before 5 years of age because there is either age variation in the acquisition of many motor skills or a lack of stability of outcomes [7]. In most cases a careful clinical examination shows signs of neurodevelopmental immaturity, such as a choreiform limb movements, mirror movements, and other associated motor characteristics, as well as signs of impaired gross and fine motor skills. According to the 10th edition of the International Classification of Diseases (ICD-10) three subgroups can be observed within the DCD: gross motor dysfunction, fine motor dysfunction (including graphomotor skills), and significant writing disorder. The basis of a correct diagnosis is an in-depth analysis of the child's medical history. Clinicians need to exclude a worsening of motor impairment over time, which could lead to the suspicion of a neurodegenerative disease. In addition, since DCD is rarely an isolated entity, extensive research of comorbid neurodevelopmental disorders, such as language disorders, autism spectrum disorder, or ADHD should be conducted. The clinical evaluation consists of self-report questionnaires addressed to parents and teachers and some tests administered directly to the child, in order to assess motor performances and other cognitive skills. The most accredited diagnostic test is the Movement Assessment Battery for children – II Edition (MABC-2) [25].

Several studies show how ADHD and DCD may be comorbid or have common characteristics with each other [26, 27] and with other neurodevelopmental disorders such as the autism spectrum disorder [28, 29]; motor control deficiencies up to an overlapping between DCD and ADHD are estimated in approximately 30-50% of the cases [30], with both conditions markedly interfering with global functioning and development, leading to worse psychosocial outcomes [30-33]. Reduced motor control and function is a common trait in individuals with ADHD [34-39]. Motor problems during developmental age can have a significant impact on overall learning and academic achievement, which is already impaired in children with ADHD. Thus, it is important to promptly identify these deficits and intervene, in order to prevent emotional disruptions linked to feelings of frustration and failure.

Therefore, the present study is aimed at investigating the presence of a DCD or motor planning difficulties in a sample of children with behavioral difficulties and/or a diagnosis of ADHD, hypothesizing how individuals with ADHD may present reduced motor function and control, with a potential impact on learning process and academic success, often already compromised in these youths.

MATERIALS AND METHODS

Participants

The present confirmatory study was conducted by assessing motor abilities in a sample of children which underwent a comprehensive diagnostic evaluation carried out by child neuropsychiatrists, psychologists, and neuro-psychomotor therapists in an outpatient service of the Child Neuropsychiatry Unit of the Department of Human Neurosciences of Sapienza University of Rome during the period from January 2021 to July 2022. The sample was selected from all the children who came to a neuropsychiatric

consultation sent by parents, teachers, and/or their pediatricians, that met the following inclusion criteria: a) age between 3 and 8 years, b) presence of behavioral problems (*e.g.*, frustration, opposition, aggression, irritability, and dysregulation), hyperactivity, attention problems, or linguistic difficulties, as assessed by the first consultation and the clinical observation of the child. Furthermore, the following exclusion criteria were considered: a) diagnosis of intellectual disability and/or autistic spectrum disorder, b) presence of neurological and/or genetic syndromes. The following socio-demographic data were gathered for all the participants: date of birth, gender, nationality. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. Parents and caregivers of all participating children provided their written informed consent. All procedures involving human patients were approved on January 31, 2018 by the ethical committee "Comitato Etico dell'Università Sapienza" (approval code 4816).

Instruments

The included subjects were administered the Movement Assessment Battery for children – II Edition (MABC-2) [25] and the Developmental Test of Visual-Motor Integration (VMI) [20], whereas their parents/caregivers were administered the Developmental Coordination Disorder Questionnaire (DCD-Q) [41].

The MABC-2 includes a standardized test and a checklist, both designed to provide complementary information on child motor performance: the performance test measures the performance in a one-to-one situation, whereas the checklist is addressed to the caregivers of children aged between 5 and 12, and provides their point of view on how the child behaves in daily life, based on a list of specific motor behaviors that can be observed in a daily context. The test consists of three sections where for each item there are four alternative answers that describe how the child copes with the task: movement in a static and/or predictable environment (section A), movement in a dynamic and/or unpredictable environment (section B), and non-motor factors that can influence movement (section C). Three different domains were observed (manual dexterity, aiming and catching, and balance), and item scores of each domain were converted into standard scores and percentiles.

The VMI is a 27-item non-verbal assessment tool of visual perception difficulties, fine motor skill problems, and hand-eye coordination deficits, addressed to individuals aged between 3 and 18. It is widely used to diagnose motor developmental disorder in youths, assessing both visual and motor abilities, as well as their integration. The 27 items measure a person's ability to accurately replicate geometric shapes of progressive complexity, requiring coordination between visual input and fine motor skills. It is particularly helpful in diagnosing developmental disorders such as DCD, and motor planning difficulties. The VMI provides insight into a child's visual-motor integration capabilities, which are crucial for academic tasks such as writing, drawing, and hand-eye coordination activities. Scores below 10 are generally considered clinical, indicating significant difficulties in visual-motor integration, whereas scores between 10 and 25 are considered subclinical, suggesting some level of difficulty but less severe than clinical cases.

The DCD-Q is a brief 15-item questionnaire addressed to parents, employed to screen for coordination disorders in children aged between 5 and 15 years old. It consists of three distinct subscales: control during movement, fine motor/handwriting, and general coordination. Parents are asked to rate their children's performance on a five-point scale, comparing their coordination with other age-matched children.

Statistical Analysis

All statistical analyses were performed using IBM Statistical Package for the Social Sciences (SPSS, Version 28.0). Data were summarized and analyzed using mean raw and weighted scores and percentiles.

RESULTS

A total of 43 children (M:F 39:4) aged between 3 and 6 years (mean age 4.5 years ± 0.7) were included in the study. All the participants were Italian. Thirty-nine subjects performed the MABC-2 and the VMI tests, whereas 41 parental couples completed the DCD-Q. Test administration and the following neuropsychiatric diagnoses were carried out by a team consisting of a child neuropsychiatrist, a psychologist, and a neuro-psychomotor therapist. Overall, 16 children (37.2%) were diagnosed with ADHD, 3 children (7.0%) with DCD, and 6 children (14.0%) with both. In the ADHD group, 7 subjects showed motor planning difficulties, whereas 6 showed grapho-motor difficulties, as observed through a child neurological visit and

neurological examination. Three cases did not show motor difficulties. All the subjects in the DCD group expressed other difficulties (namely attention difficulties, oppositional traits, and language disorder). Conversely, 18 subjects (41.9%) did not receive a diagnosis of ADHD and/or DCD, but they showed motor and behavioral difficulties: motor-praxic or graphomotor difficulties were observed in 7 children (38.8%), along with other behavioral problems such as oppositional-defiant behaviors and emotional dysregulation, or with language disorders (Table **1**).

Table 1: Socio-Demographic and Clinical Information of the Sample

Variable	N (%) / Mean (SD)
Total Sample	43
Gender	
Male	39 (90.7%)
Female	4 (9.3%)
Age (years)	4.5 ± 0.7
Nationality	100% Italian
Clinical Diagnoses	
ADHD	16 (37.2%)
DCD	3 (7%)
ADHD + DCD	6 (14%)
Motor/Behavioral Problems	18 (41.9%)

It is highlighted that, except for some particular cases in which selective mutism, language disorder or social and emotional difficulties have been diagnosed, the others still present common traits of ADHD, such as motor restlessness, attention difficulty, hyperkinetic disorder.

Analyzing the data emerged from the MABC-2 test, we can observe the following situations: 28 cases performed above the 15th percentile, 13 of which with ADHD. We note that despite the apparent absence of movement difficulties on the test, of the 13 diagnoses of ADHD, 6 have an association with grapho-motor difficulties and 4 with praxis motor difficulties; 9 cases performed between 6th and 15th percentile, 2 of which have ADHD+DCD, 3 have ADHD with motor-praxic difficulties, one DCD; 6 cases were under 5th percentile, 4 of which have ADHD+DCD and 2 DCD.

Figure **1** shows the results of the MABC-2 subdivided for diagnostic categories, with scores below 5% considered as clinical, between 6-15% as subclinical and above 16% within the range of normality.

We subsequently compared the motor performance levels between ADHD+DCD, DCD and ADHD+motor-praxic patients.

With respect to the ADHD+DCD group, children's performances were classified, based on the total score,

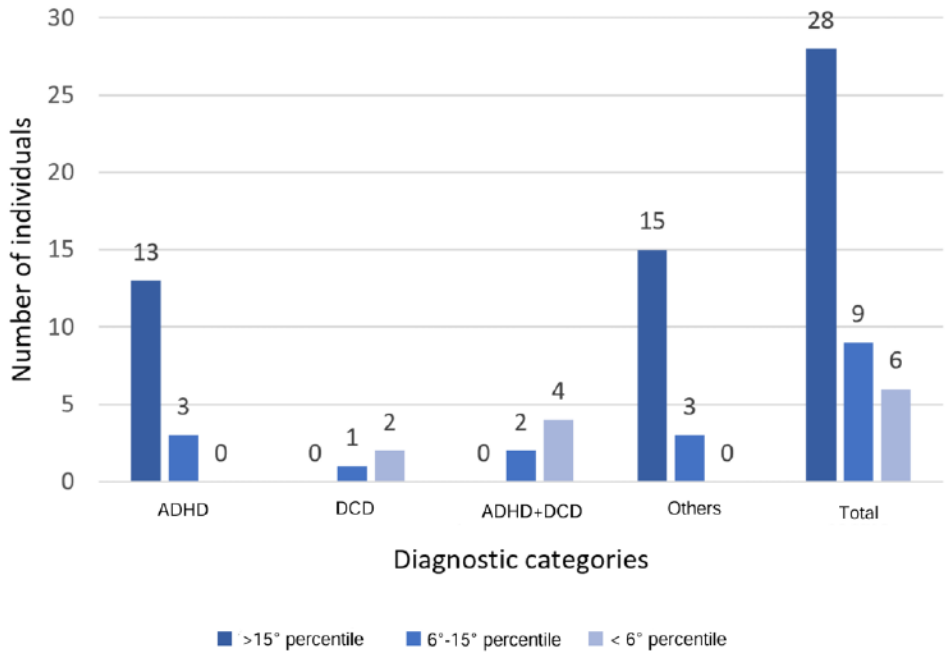

Figure 1: Percentiles observed at the MABC-2 in the total sample and according to diagnostic categories.

as either clinical or subclinical, with pitfalls observed predominantly in the balance area. The profiles appear to be non-homogeneous, with a tendency to obtain higher scores in the aiming and catching subtest (percentiles ranging between 2° and 84°) and lower scores in the balance subtest (percentiles ranging between 1° and 9°). Regarding VMI results, scores below 10 are considered "clinical" and scores between 10 and 25 "subclinical". This group of patients tend to obtain scores that can be classified as either clinical or subclinical, with worse performances in the motor coordination test (percentiles ranging between <1° and 14°), but with profiles that tend to be more or less homogeneous. In non-homogeneous profiles the strongpoints are noticed mainly in the visual perception test (percentiles ranging between 2° and 81°).

It was noted that 2 cases presented non-homogeneous profiles on the MABC-2 with higher scores in aiming and catching (75° and 84° percentile, respectively), of which the first showed a non-homogeneous profile also on the VMI with higher scores in visual perception (81° percentile), while the other presented a homogeneous VMI-profile with difficulties in all areas assessed and with a visual perception test score equal to 2° percentile.

Regarding the DCD group, it is observed that in the MABC-2 the major pitfalls are in the manual dexterity and balance areas, but with generally homogeneous profiles.

At the VMI, however, significantly different profiles are obtained, with one patient presenting important difficulties in all analyzed areas (all the percentiles <1°), one patient presenting with a non-homogeneous profile with drops in the VMI (3° percentile) and the visual perception test (4° percentile), and one with a fundamentally homogeneous profile and no particular falls in any area.

In the group including children with ADHD and motor-praxic difficulty, from the results of the MABC-2, it is noted that the profiles can be more or less homogeneous and that the major falls are in the areas of manual dexterity and balance.

VMI results reveal profiles that tend to be uneven with major falls in the area of motor coordination. Again, the highest scores are found in the visual perception test.

With respect to language, in 29 out of 43 cases (67%) there is evidence of a speech disorder or difficulty, predominantly in production, especially in the ADHD + DCD and DCD groups.

Considering the role of parents and the school in recognizing a disorder, we can compare the difficulties reported with those actually assessed by the multidisciplinary group. Similarly, we can verify whether what emerges from the completion of the DCD-Q questionnaire is also observed in evaluation.

As for the reports, 23 out of 43 cases (53%) were evaluated for hyperactivity and/or attentive difficulties and 16 out of 23 (70%) were diagnosed with ADHD. The 7 cases reported but not diagnosed for ADHD (30%) were still diagnosed for behavioral or motor difficulties: motor restlessness, motor difficulties, emotional dysregulation, attentive difficulties.

Regarding the DCD-Q questionnaire, 22 out of 39 (56.4%) cases were found to be suspected-DCD. Following the evaluation, it was noted that out of these 22 cases, 15 (68.2%) had DCD or general motor difficulties. In particular, 5 cases have DCD, 7 motor-praxic difficulties, 2 grapho-motor difficulties and one patient presented transient tic disorder. Of the 17

Table 2: Results of the Developmental Coordination Disorder Questionnaire (DCD-Q) in the Study Sample

DCD-Q Results	N (%)
Total Participants Completing DCD-Q	39
Suspected DCD	
Yes	22 (56.4%)
No	17 (43.6%)
Confirmed DCD/General Motor Difficulties	
Yes	15 (68.2% of suspected DCD)
No	7 (31.8% of suspected DCD)
DCD Types (among those confirmed)	
DCD	5
Motor-Praxic Difficulties	7
Grapho-Motor Difficulties	2
Transient Tic Disorder	1
Unsuspected DCD with Difficulties	
Yes	10 (59% of unsuspected DCD)
No	7 (41% of unsuspected DCD)

unsuspected DCD, 10 cases (59%) still had DCD or general motor difficulties; in particular 4 were diagnosed with DCD, 2 had motor-praxic difficulties and 4 presented grapho-motor difficulties. The remaining 41% do not actually have motor difficulties. Results of the DCD-Q are summarized in Table **2**.

DISCUSSION

At the end of the study, 51% of participants were diagnosed with ADHD, while 20% were diagnosed with DCD. Nevertheless, the primary finding emphasizes the significance of considering all aspects of a child's functional level, in addition to the specific diagnosis, when planning early therapeutic interventions.

The results of the study confirmed, with respect to the initial hypothesis and prior scientific literature of the field [30, 33-35], an increased prevalence of DCD or general motor difficulties in children with ADHD compared to the general population. Specifically, 27.3% of ADHD patients received a double diagnosis of ADHD+DCD, while 31.8% have documented motor-praxic difficulties.

These findings are consistent with literature reports of a 30-50% comorbidity rate between the two disorders, and more in general of motor control impairment in ADHDs.

Furthermore, neuropsychomotor evaluations showed that subjects with ADHD+DCD have behavioral patterns characterized by attention difficulties, hyperactivity, and impulsivity, that are present also in the free-play contexts; such features (especially inattention)recurred also during the administration of the MABC-2 test, thus affecting the performance level. It could therefore be argued that the motor difficulties present in children with ADHD may be the direct consequence of the pivotal symptoms of the disorder.

With respect to the most compromised areas, a common datum is that in all subjects the main deficits concern balance, but in the DCD and ADHD+motor-praxic groups manual dexterity is equally affected. Furthermore, another similarity between the ADHD+DCD and the DCD groups, detectable at the VMI test, is that both sets of patients show a major shortfall in the motor coordination test, whereas for the ADHD + motor difficulties group the results tend to be less predictable.

Regarding the DCD-Q questionnaire and the referral cause, it is evident that the parents and teachers play a key role in the early recognition of the children's difficulties and in the assessment of their daily functional level. Hence, it is fundamental to sensibilize parents and teachers to a diligent observation of the children to be able to identify precociously and with increased awareness potential difficulties.

School staff should be trained in order both to be able to screen children for neurodevelopmental disorders and to take active part in a home-school-therapy trivalent intervention.

Hence, it appears crucial to start an early intervention on behavioral, attention and hyperactivity symptoms, but at the same time it is fundamental not to neglect the motor difficulties.

In particular, therapeutic interventions should on one hand focus on improvement of attention maintenance, planning skills, reinforcement of inhibitory control and more in general of executive functions; and on the other in refining motor skills both on a gross and fine motor level.

Regarding ADHD therapeutic sessions, it is suggested at the beginning to work in a setting with few distracting stimuli, to create a visual agenda of the activities that will be carried out, to use a clock to delimit each individual tasks, to utilize positive reinforcements and to have frequent breaks, alternating free play and structured activities. Moving forward on the interventional project, these supports should be gradually removed to lengthen session times and to reinforce the child's ability to manage distractions.

With respect to motor difficulties, work should focus on ameliorating body awareness and sensory perception, in order to improve gross and fine motor abilities, eye-hand and bi-manual coordination and balance. Finally, these two aspects (motor control and executive functions) should also be targeted together, with a transversal work focusing on planning, attention, and problem solving.

Concomitantly, psychological repercussions should not be underestimated: ADHD children seem to participate less in social activities due to behavioral problems and difficulties in emotional regulation. Additionally, there is evidence of an increased risk of

developing psychiatric conditions such as anxiety, mood disorders, substance abuse and antisocial personality disorder. These relational difficulties seem to be correlated to less flexibility when responding to environmental changes and poor behavioral and affective self-regulation resulting in rejection and marginalization.

Regarding DCD children, they seem to have a tendency to low self-esteem, due to their perception of being less competent than their peers in school skills such as writing, drawing but also games and sports, with repercussions on their social participation. In fact, DCD has also been associated with depression, anxiety and social impairment, with an even higher risk of social exclusion in ADHD+DCD subjects.

The main limitations of this study are a small sample size and a selection bias due to participants being enrolled not from the general populations, but among the population that referred to our hospital. It would be ideal to carry out a longitudinal study in order to verify the effectiveness of early therapy initiation at a preschool age, both in children who received a diagnosis and in children with difficulties typically observed in ADHD and DCD but that do not meet their diagnostic criteria.

CONCLUSIONS

The present study confirms a significant overlap between ADHD and DCD, highlighting the prevalence of motor difficulties in children with ADHD. The results align with prior literature, suggesting that motor impairments, especially in balance and manual dexterity, are also common in ADHD patients. Early therapeutic interventions targeting both motor and behavioral difficulties are crucial in improving functional outcomes and preventing future complications in learning and social interactions. Further longitudinal research is needed to assess the long-term benefits of early interventions in this population.

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Declaration of Interest Statement

The authors report there are no competing interests to declare.

Author Contributions

Conceptualization, Maria Teresa Giannini, and Maria Romani; Data curation, Valerio Zaccaria, Maria Teresa Giannini and Maria Romani; Formal analysis, Maria Teresa Giannini; Methodology, Valerio Zaccaria, Alice Innocenti, Giuliano De Meo, Maria Teresa Giannini and Maria Romani; Supervision, Maria Romani; Writing – original draft, Valerio Zaccaria, Alice Innocenti and Giuliano De Meo; Writing – review & editing, Valerio Zaccaria, Alice Innocenti and Giuliano De Meo.

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