rijksuniversiteit groningen / faculteit gedrags- en maatschappijwetenschappen

A correlational study, the relationship between sustained attention and gross and fine motor skills in children with a Developmental Coordination Disorder.

Ellis Koning

Master Thesis - Klinische Neuropsychologie

S3673839

17 juli 2024

Department of Psychology

University of Groningen

Examiner/Daily supervisor:

Dorothee Jelsma

Abstract

Problems of attention and inhibition are evident in neurodevelopmental disorders, including a Developmental Coordination Disorder (DCD). Less proficient inhibition is related to worse motor performance. The processes underlying inhibition may be depending on selective, divided, or sustained attention. This study examined the relationship between sustained attention and gross and fine motor skills in children with DCD. Twenty-three Dutch children of 6 to 12 years participated in this study. A Pearson correlation test was performed on variables including cognitive and motor scores measured by the Movement Assessment Battery for Children-2 and the Test of Everyday Attention for Children. For motor skills, almost all children had a scaled score that could be classified as impaired, as would be expected given that low motor skills was an inclusion criterion. About half of the children scored impaired on sustained attention. A relationship between motor skills and sustained attention has not been found. More research on attentional capacities in children with DCD would be recommended.

Introduction

A Developmental Coordination Disorder is a neurodevelopmental disorder, classified in the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) within the subdomain of motor disorders (American Psychiatric Association, 2013). The main criteria of DCD, as described in the DSM-V is: ‘the acquisition and execution of coordinated motor skills is substantially below that expected, given the individual’s chronological age and opportunity for skills learning and use’ (APA, 2013). In children with DCD, difficulties are manifested as clumsiness, slowness, and inaccuracy in performance of motor skills. Deficits in motor skills are persistent and interfere with activities of daily living. The onset of DCD symptoms is in the early developmental period. The motor deficits cannot be better explained by intellectual disabilities, visual impairments or another neurological condition affecting movement (e.g., cerebral palsy or a degenerative disorder) (APA, 2013).

Motor skills refer to the underlying internal pathways responsible for moving the body through space as well as the cognitive processes that give rise to such movements (Sorgente et al., 2021). Motor skills can be divided into two categories, namely gross motor skills and fine motor skills. Gross motor skills involve the body’s large muscles and pertain to movement of the trunk and limbs whereas fine motor skills involve the body’s small muscles and pertain to movements of wrists and fingers (Sorgente et al., 2021). Examples of gross motor skills are jumping, walking, throwing, catching, and balancing tasks. Examples of fine motor skills are building a tower with bricks, drawing tasks, tying shoelaces, cutting and buttoning a shirt. In a study of Schott et al. (2016), children with DCD showed more errors and a slower and less accurate performance in a fine motor dual task (with a concurrent cognitive task), compared to typically developing children. Children with DCD performed more poorly in the fine motor control task than in the gross motor control task. For this reason, gross and fine motor skills will be analyzed separately in this study. The cognitive load of the task seems to play a role in performance (higher cognitive load seems to lead to worse performance).

There are multiple explanations for motor deficits in children with DCD. One explanation is the inhibitory deficit hypothesis. This hypothesis states that reduced inhibition may underpin or contribute to compromised motor skills in children with DCD (O'Halloran et al., 2014). A second hypothesis based on motor control deficits in DCD, concerns the internal modeling of movements. According to the internal modeling deficit (IMD) hypothesis, children with DCD have a reduced ability to utilize predictive motor control (Wilson & Butson, 2007). Another prominent explanation is the automatization deficit hypothesis. Automaticity in the context of fine and gross motor control refers to the ability of the nervous system to successfully control e.g., typical steady state walking, effortlessly even when attention is directed elsewhere, and without paying attention to the movements being produced (Schott et al, 2016). The interference between motor and cognitive performance may result from the fact that the attentional focus must be repeatedly switched, in a time-critical manner, between information processing, and control operations for adjusting motor performance (Schott et al., 2016).

In the literature, a strong shared additive genetic component was found between Attention Deficit Hyperactivity Disorder (ADHD) and DCD (Watemberg et al., 2007). Both disorders have been found to co-exist with each other with a comorbidity rate as high as 50% (Loh et al., 2011) and both show problems in attention as well as performance of gross and fine motor skills. There is more research to be found on attentional problems in ADHD compared to DCD. One explanation could be that in DCD, motor problems are more prominent and attentional problems can occur to be more in the background.

In the few studies that included children with DCD, deficits in attention and processing speed are seen. In one study, thirty-six children with DCD were included, more than 50% of this group of children were categorized as impaired on sustained attention, attentional control, and non-motor processing speed. In this study, the prevalence of symptoms of inattention, hyperactivity, and executive functioning difficulties among children ranged from 58% to 86%, when adjusting for probability of ADHD, intelligence, and socioeconomic status. The observed differences between typically developing children and children with DCD were statistically significant and of a considerable magnitude, particularly in auditory sustained attention and attentional control (Bonthrone et al., 2023).

Attention is a broad and important neuropsychological domain which is regulated in the brain, specifically in the frontal cortex. Other brain regions, such as the orbito frontal cortex, insula, and cerebellum also play an important role in attentional and executive functions (Querne et al., 2008). A neuroimaging study indicated several brain areas linked to DCD: the cerebellum, basal ganglia, parietal lobe, and parts of the frontal lobe (medial orbitofrontal cortex and dorsolateral prefrontal cortex). The cerebellum seems to be related to uncoordinated behaviors, clumsiness, poor coordination, and postural control. The basal ganglia appears to play a key role in motor control, movement initiation, movement learning, and automatization (Biotteau et al., 2016). In children with motor deficits, there seem to be brain differences compared to children without motor deficits. The decreased functional connectivity between the primary motor cortex, the striatum and the angular gyrus was observed in children with DCD, ADHD, and DCD + ADHD (McLeod et al., 2014). This suggests that these brain regions may be common neurophysiological substrates underlying disorders as DCD and ADHD (McLeod et al., 2014).

Attention is an important component in the performance of motor skills. Attention is necessary for giving proper use of sensory feedback. Coordinated voluntary movement requires this real-time sensory feedback (Tseng et al., 2004). Sustained attention is a core cognitive component upon which many higher-level cognitive processes critically depend.

Sustained attention is a component of the executive system and represents the ability to focus cognitive capacity on specific stimuli or on a specific task over time. A deficit in sustained attention makes it difficult to produce fast responses (Ferrazzoli et al., 2017). It has been shown that sustained attention is impaired in a range of neurodegenerative disorders, and it is related to motor function and loss of automaticity (DeGutis et al., 2023). For example, sustained attention deficits predict decreased gait speed and are associated with low grip strength, unintentional weight loss, self-reported exhaustion, and low physical activity (O'Halloran et al., 2014). There is evidence that the inhibitory system in children with DCD is less efficient at restraining or canceling an action than in typically developing children (He et al., 2018). The processes underlying inhibition may be depending on selective, divided, or sustained attention (Jelsma et al., 2023). Other research of Reck and Hund (2011) states that children with higher sustained attention abilities exhibited greater inhibitory control.

There seems to be impairment in auditory sustained attention and visual sustained attention in children with DCD. Poorer performance, longer response times, and fewer correct responses on an auditory Continuous Performance Test (CPT) were measured compared to a visual CPT matched for difficulty on all parameters (Lewis & Greenberg, 1995). In another study it was demonstrated poorer perceptual reasoning ability in children with DCD. This research stated that deficits in visuo-spatial ability may underlie DCD but not ADHD (Loh et al., 2011).

In conclusion, deficits in sustained attention might contribute to deficits in gross and fine motor performance in children with DCD. In children with ADHD, the correlation between sustained attention and gross and fine motor skills has been explored. A study of Tseng, et al. (2004), showed that for a group of children with ADHD, sustained attention was not only correlated with both gross and fine motor skills but was also one of the best predictors of motor performance. Selective attention, divided attention, and vigilance/or sustained attention are important components of attention that have not been tested or trained much in children with DCD (Jelsma et al., 2023).

The current study will focus on this cognitive-motor relationship in children with DCD. There is relatively limited literature regarding cognitive and motor performance in children with DCD (Schott et al., 2016). If there is a relation between sustained attention and gross and fine motor skills in children with DCD, possible interventions can target motor skills but also focus on attentional capacities. Improvement of motor skills as well as attentional skills is important for functioning in daily life of children with DCD. The development of gross motor skills can contribute to higher levels of self-esteem (Tseng et al., 2004). Fine motor skills are essential to daily occupations, such as writing or typing. These daily life tasks also demand sustained attention (Tseng et al., 2004). For most children, this is an automatic process which takes minimal or no conscious effort. For children with DCD, it is a less automatic process and tasks of daily living are more difficult. Differentiating between auditory and visual sustained attention could be important for developing appropriate interventions and to optimize learning (Guy et al., 2013). For instance, if problems in auditory sustained attention are seen in children with DCD, advice could be to give shorter instructions to these children. This could increase the functional capacity of children with DCD.

In this study, the gross and fine motor skills as well as sustained attention of children with symptoms or a diagnosis of DCD will be measured. The hypothesis for the current study is that there is a relationship between sustained attention and gross and fine motor skills in Dutch children with symptoms or a diagnosis of DCD in the age of 6 to 12. Because the gross and fine motor skills will be analyzed separately, there are two research questions for this study. The research questions are as follow:

1. “Is there a relationship between sustained attention and gross motor skills in Dutch children with symptoms or a diagnosis of DCD in the age of 6 to 12?”

2. “Is there a relationship between sustained attention and fine motor skills in Dutch children with symptoms or a diagnosis of DCD in the age of 6 to 12?”

Method

Participants

The participants (*N* = 23) in this study included Dutch children aged 6 to 12 years with symptoms or a diagnosis of DCD. The children were recruited through pediatric physiotherapy practices and three different primary schools. Of all participants, there were 13 boys and 10 girls. In addition to DCD (43.5%), other observed comorbidities include ADHD (13%), ASS (4.3%), and language development disorders (8.7%). Eighteen children participated in a sport; two children did not participate in a sport. Three children already receive physiotherapy twice a week (including the fit4sport program). Examples of mentioned sports are swimming, judo, soccer, horse riding, boxing, and scouting. On average, the children engaged in sports activities 2,02 hours a week (including the physiotherapy program). There were twelve children from special education schools and eleven children from regular schools.

Table 1.

Descriptive data of the participant group. The mean and standard deviation for weight, length, and age, included with the number of respondents.

	Mean	**Standard deviation**	**Respondents**
Weight (kg)	36.87	12.25	14
Length (cm)	141.92	10.75	12
Age	8.57	1.88	23

To assess the symptoms and or diagnosis of DCD, a few aspects were screened for inclusion. First, the motor capacities of the children were tested by the Movement Assessment Battery for Children (MABC-2), if the children scored in the range of 'risk for motor problems' (scaled score of 6 or 7) or 'motor problems' (scaled score below 6), the children could be included. Also, the children had to meet the DSM-V criteria for DCD. Children were excluded based on an IQ of below 70, a scaled score higher than 7 on the MABC-2, repeating a class more than twice and having another medical or neurological disease affecting motor performance. Information regarding the exclusion criteria was collected from school files. The recruitment method for this study was purposive sampling. The participants were elected based on a certain characteristic; symptoms of DCD. The ethical guidelines were accounted for in this study by the declaration of Helsinki. This study has been approved by the Ethical Committee Psychology with the corresponding code: PSY-2223-S-0438.

Neuropsychological tests

To measure sustained attention, the Test of Everyday Attention in Children (TEA-Ch) was used. The raw scores were converted into scaled scores in accordance with the provided normative tables, which corresponded to the appropriate age range and gender. Impaired performance on the subtests of the TEA-Ch is defined as a scaled score of 6 or less (Araujo et al., 2017).

Five subtests measure sustained attention (Evans & Preston, 2011). These are: Score!, Score dual task, Sky search dual task, Walk don't walk and Code transmission. In the Score! task, children need to count computer game sounds played by the CD (auditory task). The Score dual task requires children to count the same computer game sounds as in the Score! task, and simultaneously tell the name of an animal which is named in a news report on the CD (double auditory task). Before starting with the dual task, both the single tasks are practiced once. In the Sky search dual task, children are instructed to search for up to 20 equally looking spaceships while counting computer game sounds (visual auditory task). In the Walk don't walk task, children are instructed to make marks on a piece of paper with printed footsteps. The CD plays different tones. One tone gives a sign to 'walk', where children need to make a mark on the printed footsteps. Another tone gives them a sign to stop 'walking', children do **not** need to mark the printed footprints and stop at the appropriate time (before the next sound plays). As the task progresses, the tones are getting faster (auditory task). The Code transmission task requires children to listen to the CD that plays numbers between 1 and 10, children must name the number that is mentioned every time before the number five is called two times (auditory task).

The TEA-Ch scores 'good' on the domains: test construction, quality of the test material and quality of the manual. The norms, reliability, construct validity and criterion validity are classified as 'insufficient' by the COTAN (Evers et al., n.d.). The norms give no information about the type of standard scores, means, standard deviations or confidence intervals.

Motor tests

To measure gross and fine motor skills, the Movement Assessment Battery for Children, second edition (MABC- 2) has been used. The raw scores are converted into scaled scores by making use of the normative table, corresponding with the right age. There are three different age bands for this test, all age bands are used in this study. These age bands have different test-items, appropriate to age. There are three components in the MABC-2: Manual dexterity, Aiming/catching and Balance (Henderson et al., 1992).

Age band 1(3-6 years)

The Manual dexterity domain includes three subtasks. The first task is posting coins in a money bank with the preferred and non-preferred hand, as fast as possible. The second task is threading beads as fast as possible. The third task involves drawing a trail between two lines while the trail needs to stay between the two lines.

Aiming/Catching includes two subtasks. The first task contains catching a thrown beanbag. For the second task, children need to throw a beanbag onto a target.

The Balance domain has three tasks. For the first task, the children need to balance on one leg (best leg and other leg). The second task is walking on raised heels. In the last subtest of this domain, children need to jump forwards on mats.

Age band 2 (7-10 years)

The manual dexterity tests consist of three subtasks. The first task requires the children to place little pegs into a board as fast as they can (with the preferred and non-preferred hand). In the second task, children need to thread a lace through holes of a board, as fast as possible. For the last task, the children need to trace a route with a pencil, while they need to stay between two lines (the space between the lines is thinner compared to age band 1).

The Aiming/catching part consists of two tasks. The catching task involves the children throwing a tennis ball against a wall and catching the ball with two hands. The throwing task requires the children to aim a beanbag onto a red circle on the target.

The Balance domain involves three subtasks. In the first task, children need to balance on a board with one foot (best leg and other leg). The second task requires children to walk step by step along a line on the floor heel-to-toe. For the last task, children need to hop on a few mats on one foot (best leg and other leg).

Age band 3 (11-16 years)

In the Manual dexterity domain, children need to turn small two-colored pegs plugs as fast as possible, to change their color (with the preferred and non-preferred hand). In the second task, the children need to create a triangle with nuts and bolts (as fast as possible). For the third task, the children need to draw a trail between two lines (the shape of the trail has changed compared to age band 2).

In the domain of Aiming and catching, the catching task must be done with one hand (instead of two, see age band two), this will be tested with the preferred hand as well as the non-preferred hand. For the second task of this domain, the children need to throw a ball at a target on the wall.

Within the Balance domain, the first task requires children to stand on the board with two feet (instead of one foot) heel to toe placed. The second task is the same as the second task from age band two, but the children need to walk backwards instead of forwards. For the last subtask the children need to hop on mats diagonally instead of forwards (with the best leg and other leg).

In the appendix, a clear overview of all the tests per age band can be found (appendix 1). The MABC-2 displayed a good intraclass correlation of 0.96 across items. A value of 0.77 was obtained for test–retest reliability (Chow & Henderson, 2003)

Questionnaires

SDQ (Strengths and Difficulties Questionnaire)

The SDQ is a questionnaire filled out by the parents of the children. The SDQ contains 25 items, based on five different categories; Emotional symptoms, Conduct problems, Inattention-hyperactivity, Peer problems, and Prosocial behavior (Van den Heuvel et al., 2017). The scale of the SDQ ranges from 0 to 2 points per item (0 = ‘not applicable’, 1 = ‘a bit applicable’, 2 = ‘very applicable’). The Inattention-hyperactivity scale is used for the current study to give some information about the attentional capacities and hyperactivity problems in the daily life of the children. The Inattention-hyperactivity scale has five items, containing questions regarding restlessness, concentration, impulsivity and sustaining attention (e.g., cannot sit still for long, wobbling, often distracted, not thinking before doing something and difficulties finishing tasks). The minimum score for this scale is 0 and the maximum score is 10. The SDQ has been classified as ‘sufficient’ on test construction, reliability, and construct validity. Quality of the test material has been classified as ‘good’. The other criteria: quality of the test manual, norms and criterion validity have been classified as ‘insufficient’ by the COTAN (Evers et al., n.d.).

KIDSCREEN-10

The KIDSCREEN-10 is a questionnaire that measures the Health-related Quality of Life of children. This questionnaire contains 10 items and can be globally divided into two domains. One domain focuses on positive emotions (8 items) and one domain on negative emotions (2 items). Each item has a five-point response scale, ranging from 1-5 (1 = ‘not at all’, 2 = ‘a little’, 3 = ‘moderately’, 4 = ‘much’ and 5 = ‘very much’). The minimum score on the positive emotions scale is 0 and the maximum score is 40. Higher scores indicate more positive emotions. For the negative emotions scale the minimum score is 0 and the maximum score is 10. In this case, higher scores indicate more negative emotions. Regarding reliability, Cronbach’s alpha was 0.82 for the KIDSCREEN-10 self-report (Ravens-Sieberer et al., 2010).

Procedure

The design of this study is a cross-sectional design. Participating in the project was voluntary, participants could stop at any moment without a given reason. Before testing, the parents and participants needed to give consent. The TEA-Ch and the MABC-2 were executed by different researchers. The researchers were trained in administering these tests. Most of the time, there were two researchers present when testing. Instructions for these tests were given as described in the test manuals, to make it as standardized as possible. The children filled out the KIDSCREEN-10 together with one or two assessors. The SDQ was given to the parents to be filled out. The parents of the children were not present when testing the child since this may influence the test performance. The tests were conducted in different rooms. The MABC-2 was performed in gym rooms at the schools, with one assessor present per child. For the fine motor task, a chair and table were necessary to carry out the tasks. For the gross motor task, no additional material was needed (apart from the standard test material). The TEA-Ch was administered in a smaller room with just one child each time. The order in which the tests were applied differed per child. Sometimes the TEA-Ch was applied first and sometimes the MABC-2. The data has been collected on multiple days. Two children dropped out of the study before assessment of the TEA-Ch. For some children one day of testing was enough but other children needed another day. This was due to convenience and planning. The children got a small gift after completing the tests. Specific instructions for each test can be found in the corresponding test manuals.

Statistical analyses

The data was checked on normality and outliers. A Pearson correlation test has been done to test the main research questions; is there a relationship between sustained attention and gross and fine motor skills in Dutch children with symptoms or a diagnosis of DCD in the age of 6 to 12? Gross and fine motor skills have been analyzed separately. To determine the strength of the correlation coefficients, the classification of Dancey and Reidy (2007) has been used (appendix 2). The outcome variables: sustained attention, gross motor skills and fine motor skills were measured in component standard scores. Missing values have been examined. If there were no more than two missing values, the mean of the group has been used to fill in the missing values. If there were more than 2 missing values, only the accessible data was used for calculations. For the variable sustained attention, the mean scaled scores of the five separate tests of the TEA-Ch were used to calculate a component scaled score for total sustained attention. For fine motor skills, the mean scaled score on manual dexterity has been used. For gross motor skills, the mean scaled score on aiming and catching and the mean scaled score on balance have been used.

Some additional analyses were conducted to provide a more comprehensive understanding of the data. First, individual correlations between each of the five subtests of the TEA-Ch, measuring sustained attention, and the domains of the MABC-2, measuring gross and fine motor skills. By exploring these individual correlations, the analysis provides insights into the potential connection between a specific sustained attention task and gross and fine motor tasks. It can help identify possible differences in auditory, double auditory and visual sustained attention tasks regarding gross and fine motor skills. Secondly, a frequency table has been calculated for total sustained attention and the total MABC-2 to demonstrate what cumulative percentage of the children scored equal or below a scaled score of 6 (in the impaired range). Thirdly, the results on the SDQ and KIDSCREEN-10 have been explored by a descriptive analysis. Average scores on the items of the Inattention-hyperactivity scale of the SDQ and the items of the positive and negative emotion scale of the KIDSCREEN-10 were computed to offer a broader insight into the characteristics of the participant group in the current study. The program IBM SPSS Statistics 28 has been used for the calculations.

Results

First, the relation between gross motor skills and sustained attention has been analyzed, the component standard score of aiming / catching was not significantly correlated with the component standard score of total sustained attention, a weak correlation was found (r = -.122; p = .580; N = 23). The same results apply for balance, this was also non-significant weak correlation (r = -.216; p = .321; N = 23). The negative correlations found in the study, even though very weak and not statistically significant, indicate that there is a slight tendency for higher scores in gross motor skills to be associated with lower scores in sustained attention, or vice versa. Possible explanations for this are a small sample, task demands or characteristics of the sample (e.g. severity of symptoms, co-occuring conditions). Secondly, the relation between fine motor skills and sustained attention has been analyzed. The component standard score manual dexterity was not significantly correlated with the component standard score total sustained attention (r = .038; p = .862; N = 23).

Additionally, a Pearson correlation test for all the separate items of the TEA-Ch showed that none of the separate items were significantly correlated with any specific domain of the MABC-2. Looking at the separate subtests of the TEA-Ch, especially the 'Walk don't walk' task score is in the impaired range. For the domain of the MABC-2, balance has the lowest scaled score. Table 2 gives an overview of the mean scores, minimum and maximum scores of the children on the different subtasks and their total performance.

A frequency table for total sustained attention showed that 47.8 % of all the children (N = 21) score in the impaired range. A frequency table has also been made to look at the cumulative percentages of the scaled scores of the MABC-2. As expected, 95,7 % of the children (N =23) score in the impaired range.

The descriptive data from the SDQ and the KIDSCREEN-10 are displayed in table 3.

Table 2.

The mean scaled scores, standard deviation (SD) per measured variable. The minimum and maximum scaled score of the children of this study is displayed, including the number of respondents.

Domain	***Mean (SD)***	***Minimum***	***Maximum***	***Respondents***
MABC-2: Total	*3.04 (1.61)*	*1*	*6*	*23*
MABC-2:				
Manual Dexterity	*5.3 (2.95)*	*1*	*12*	*23*

MABC-2: Aiming / Catching	*5.52 (2.59)*	*1*	*10*	*23*
MABC-2: Balance	*3.22 (1.73)*	*1*	*7*	*23*
TEA-Ch: Sustained Attention Total	*5.77 (2.66)*	*1*	*6*	*21*
TEA-Ch subtest 1: Score!	*8.14 (3.62)*	*3*	*14*	*21*
TEA-Ch subtest 2: Sky search (dual task)	*6.8 (6.19)*	*1*	*13*	*18*
TEA-Ch subtest 3: Score (dual task)	*6.18 (3.05)*	*0.1*	*19*	*21*
TEA-Ch subtest 4: Walk don't walk	*4.27 (1.67)*	*2*	*14*	*21*
TEA-Ch subtest 5: Code transmission	*6.09 (2.99)*	*1*	*7*	*21*

Table 3.

The mean, minimum, maximum possible score on the Inattention-hyperactivity scale of the SDQ questionnaire and the positive and negative emotions scale of the KIDSCREEN-10 questionnaire, including the number of respondents.

	Mean (SD)	*Minimum*	*Maximum*	*Respondents*
SDQ				
Inattention-Hyperactivity scale	*4.6 (2.61)*	*0*	*10*	*15*
KIDSCREEN-10				
Positive emotions scale	*32.25 (4.25)*	*0*	*40*	*23*
Negative emotions scale	*4.78 (1.81)*	*0*	*10*	*23*

Discussion

The aim of this study was to investigate the relationship between sustained attention and gross and fine motor skills in children with DCD. In the current study no relationship was found between sustained attention and gross and fine motor skills. Nevertheless, the current study revealed that almost half of the children exhibited impairments in sustained attention. This finding is consistent with those of Bonthrone et al. (2013), who also observed sustained attention problems in children with DCD. In almost all children motor deficits are observed, as expected considering the inclusion criteria. The results of the SDQ imply that inattention/hyperactivity does play a role for the children within the current study. Positive and negative emotions of the children were examined by the KIDSCREEN-10. The children scored above average (32 out of 40) on positive emotions and average (5 out of 10) on the negative emotions.

There appear to be no differences in the nature of the sustained attention tasks (auditory or visual), except for the 'walk don't walk' task. The ‘Walk don’t walk’ task is also a good measure of inhibition. Difficulties in the inhibitory system in children with DCD are displayed in the literature (He et al., 2018). In the current study, inhibition problems are also evident as the 'Walk don't walk' task seems to be the most difficult task for the children. This result supports the hypothesis of reduced inhibition in children with DCD. Less proficient inhibition is related to worse motor performance (Gálvez-García et al., 2018). Research of Reck and Hund (2011) states that children with higher sustained attention abilities exhibited greater inhibitory control. The impaired scores on sustained attention may be related to inhibitory control. Research by Tseng et al. (2004) found that sustained attention was one of the best predictors of motor performance. Inhibitory control was another important predictor. Together they explained 45.7% of the variance in gross and fine motor performance in children with ADHD. The current study focused only on sustained attention and less on inhibition.

There are several potential explanations for the absence of a relationship between gross and fine motor skills and sustained attention. The study of Tseng et al. (2004), suggests that short or timed motor tests are unlikely to place a heavy demand on sustained attention. This could be one explanation for the non-significant results in the current study. The MABC-2 has been used in the current study, but several of the tasks in this instrument are of short duration. For example, the balance domain has a static balance task, where the children can reach a maximum of 30 seconds. The manual dexterity tasks are also relatively short timed tasks. The MABC-2 tasks measuring gross and fine motor skills, may not be long enough to place a sufficient demand on sustained attention. A relationship between inhibition and motor performance has not been explored in the current study, but might be present looking at the findings in the literature and the low scores on the Walk don't' walk task of the TEA-Ch.

The results of the SDQ, completed by the parents of the children, suggest that inattention/hyperactivity does play a role for the children in the current study. Previous research demonstrated a relationship between sustained attention and gross and fine motor skills in children with ADHD (Tseng et al., 2004). High comorbidity between ADHD and DCD has been shown in the literature (Loh et al., 2011). Symptoms of ADHD, such as inattention and hyperactivity might have contributed to the impaired scores on the sustained attention measures of the TEA-Ch. This might have influenced the possible relationship of sustained attention and gross and fine motor skills.

According to a study of Chen et al. (2009), children with DCD are more withdrawn, depressed, underactive, or solitary than children without DCD. This contradicts the findings of the current study, where positive emotions were more prevalent. One explanation for this could be that the KIDSCREEN-10 is a self-reported questionnaire, the children answered the questions themselves. The research of Berman et al. (2016) showed that children reported slightly higher wellbeing in comparison to parental ratings. Self-report versus parent report might be a factor influencing the results of the SDQ and the KIDSCREEN-10.

There are several limitations in this study. For inclusion, the motor skill performance of the children was screened by the MABC-2. As a result of this, the range of scores on the MABC-2 is small. Only children with low scores were included in the current study and this may have influenced the results. The variability in sustained attention scores was also small, most of the children in this study revealed problems in sustained attention. Due to range restriction in test scores, the correlation obtained is expected to be an underestimate of the correlation in the population (Henriksson & Wolming, 1998). If the group would be more variable (e.g., also including typically developing children), the chance of finding differences or a relationship would be higher. Further, the group of children was small. This influences the results and limits the power of the study. In one screening of 944 children, a prevalence rate of 3.8% was found for DCD (Sujatha et al., 2020). The low prevalence rate makes it hard to recruit a big group of participants. Another explanation for the unexpected results could be the choice of test instruments. The TEA-Ch is classified as ‘insufficient’ on some domains by the COTAN, especially the norms and criterion validity. However, this instrument was used, since this was the best instrument available for the researchers. In the current study, the order of the different subtasks of the TEA-Ch has been changed in some cases. This was due to convenience or scarcity of materials when testing two children at once. This makes the assessments less standardized and lowers the validity and reliability of the current study. At last, the current study has a few missing values. The TEA-Ch has not been completed for every child, due to errors or dropouts. This makes the overall results less generalizable.

The motor skills deficits and sustained attention deficits can influence many areas in the life of children with DCD. Improvement of motor skills can contribute to higher self-esteem and better daily life tasks performance, where sustained attention is an underlying factor (Tseng et al., 2004). For successful participation in daily life, children with DCD require practicing motor skills, but also practicing tasks in which attention needs to be divided between two or more information sources (Jelsma et al., 2023). Different programs are developed for children with DCD, targeting muscle strength, anaerobic power, motivation, and behavioral intervention (Braaksma, 2020). To improve attentional abilities, it can be necessary to give goal-based rehabilitation that entails the use of attention where the children need to switch their attention, sustain attention, or divide attention. Training with playing active video games (Wii Fit and Xbox Kinect) improved attentional abilities after playing five weeks of active video games in children with and without DCD (Jelsma et al., 2023). Children with DCD could benefit from this kind of training program. Recent evidence shows gains in motor performance following a Cognitive Orientation to Occupational Performance (CO-OP) intervention are accompanied by a sustained increase in white matter microstructure and functional connectivity between brain networks associated with emotion regulation, action inhibition, and attention for those with DCD (Subara-Zukic et al., 2022). Another important point would be to involve the parents or caregivers in the process and provide information about DCD to the environment of the child.

The aforementioned points could be addressed through improvements to the methodology, such as the use of more valid instruments, motor tasks of a longer duration, and a larger sample size. More research to attentional capacities in children with DCD would be useful in the future, since not much research has been done regarding this topic. This could give a broader image of how sustained attention is expressed in children with DCD and make sure to give them a fitting intervention, not only focusing on motor performance. A more complete image of DCD could contribute to a better understanding and optimal quality of life in children with DCD, allowing them to reach their full potential.

Conclusion

It can be concluded that the majority of children included in the study exhibited impaired motor performance, in accordance with the established inclusion criteria. Additionally, approximately half of the children in the study demonstrated impaired sustained attention. The results of this study do not provide evidence of a relationship between sustained attention and gross and fine motor skills. Further research into the attentional capacities of children with DCD is recommended.

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Appendix

Appendix 1 Age band task MABC-2

Table 4.

Outline of the different task per age band of the MABC-2 (Schulz et al., 2011)

Table 1
Individual tasks and scores obtained for each age band in the M-ABC-2 test.

Tasks	Age band 1, 3–6 years	Age band 2, 7–10 years	Age band 3, 11–16 years	Raw score
Manual Dexterity (MD)				
MD1	Posting coins Preferred hand[a] Non-preferred hand	Placing pegs Preferred hand[a] Non-preferred hand	Turning pegs Preferred hand[a] Non-preferred hand	Completion time in seconds
MD2	Threading beads	Threading lace	Triangle with nuts and bolts	Completion time in seconds
MD3	Drawing trail 1	Drawing trail 2	Drawing trail 3	Number of errors
Aiming and Catching (AC)				
Catch	Catching beanbag	Catching with two hands	Catching with one hand Best hand Other hand	Number of correct catches out of 10
Throw	Throwing beanbag onto mat	Throwing beanbag onto mat	Throwing at wall target	Number of correct throws out of 10
Balance (BAL)				
Static BAL	One-leg balance Best leg Other leg	One-board balance Best leg Other leg	Two-board balance	Number of seconds balanced (to maximum of 30)
Dynamic BAL1	Walking heels raised	Walking heel-to-toe forwards	Walking toe-to-heel backwards	Number of correct steps (to maximum of 15)
Dynamic BAL2	Jumping on Mats	Hopping on mats Best leg Other leg	Zig-zag hopping Best leg Other leg	Number of correct jumps/ hops out of 5

[a] Preferred hand is taken as the hand used to write/draw with.

*Note***.** Copied from Structural validity of the movement abc-2 test: factor structure comparisons across three age groups by Schulz, Henderson, Sugden & Barnett, 2011. *Research in Developmental Disabilities*, *32*(4), 1361–1369.

Appendix 2 Pearson correlation strength and corresponding classification

Table 5.

The Pearson correlation coefficient strength and corresponding classifications by Dancey & Reidy used in psychology (Dancey & Reidy, 2007).

Correlation Coefficient		Dancey & Reidy (Psychology)
+1	−1	Perfect
+0.9	−0.9	Strong
+0.8	−0.8	Strong
+0.7	−0.7	Strong
+0.6	−0.6	Moderate
+0.5	−0.5	Moderate
+0.4	−0.4	Moderate
+0.3	−0.3	Weak
+0.2	−0.2	Weak
+0.1	−0.1	Weak
0	0	Zero

Note. Copied from *User's guide to correlation coefficients*, by Akoglu, 2018. *Turkish journal of emergency medicine*, *18*(3), 91-93.