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A two-year follow-up study of executive functions in children with Developmental Coordination Disorder

Marialivia Bernardi[a*], Hayley C. Leonard[b], Elisabeth L. Hill[c], Nicola Botting[a] & Lucy A. Henry[a]

[a]Division of Language and Communication Science, City, University of London, UK

[b]School of Psychology, University of Surrey, Surrey, UK

[c]Department of Psychology, Goldsmiths, University of London, UK

[*]Corresponding author:

Marialivia Bernardi

Division of Language and Communication Science

City, University of London

London, EC1V 0HB

United Kingdom

Email: Marialivia.Bernardi@city.ac.uk

Tel: +44 (0)20 7040 8823

Abstract

Aim: Executive Function (EF) impairments have been identified in children with motor difficulties, with and without a diagnosis of developmental coordination disorder (DCD). However, most studies are cross-sectional. This study investigates the development of EF in children with poor motor skills over two years.

Method: Children aged 7-11 years (*N*=51) were assessed twice, two years apart, on verbal and nonverbal measures of EFs: executive-loaded working memory; fluency; response inhibition; planning; and cognitive flexibility. Typically developing children (TD: *n*=17) were compared to those with a clinical diagnosis of DCD (*n*=17) and those with identified motor difficulties (MD: *n*=17), but no formal diagnosis of DCD.

Results: Developmental gains in EF were similar between groups, although a gap between children with poor motor skills and TD children on nonverbal EFs persisted. Specifically, children with DCD performed significantly more poorly than TD children on all nonverbal EF tasks and verbal fluency tasks at both time points; and children with MD but no diagnosis showed persistent EF difficulties in nonverbal tasks of working memory and fluency.

Interpretation: Children with DCD and MD demonstrated EF difficulties over two years, which may impact on activities of daily living and academic achievement, in addition to their motor deficit.

What this paper adds

- EF difficulties in children with poor motor skills persist throughout middle childhood.
- Children with motor difficulties (MD), without a DCD diagnosis, demonstrate less pervasive EF difficulties than children with DCD.
- EF difficulties in MD and DCD groups affect mostly nonverbal domains.
- All groups showed similar developmental gains in EF.

Running Head:

Development of Executive Functions in DCD

Developmental Coordination Disorder (DCD) is a condition affecting 5% of the population[1] diagnosed on the basis of a significant motor coordination impairment impacting on activities of daily living, in the absence of any physical, neurological or intellectual disability. Individuals with DCD not only experience a motor coordination deficit but also report difficulties with personal organisation, planning, time management, memory, and decision making, which continue into adulthood[2]. These skills are underpinned by cognitive processes known as executive functions (EFs) that regulate, monitor and control behaviour towards a goal[3]. EFs are a strong predictor of academic achievement throughout childhood[4] and continue to predict general success in life during adulthood[5]. Therefore, understanding EFs in DCD is crucial for improving life outcomes for individuals with motor coordination impairments.

Previous research has identified EF deficits in children with DCD or poor motor skills (see Wilson et al.[6], and Leonard and Hill[7] for recent reviews). However, this research is largely cross-sectional. To date, two studies have assessed EF longitudinally in early childhood: in 5-6 year-old children with poor manual dexterity skills[8]; and in 4-6 year-olds screened for motor difficulties[9]. In both studies, children were followed-up one year later and those with persistent motor impairments demonstrated performance gains with age in EF tasks. However, poorer EFs were identified at both time points when compared to a sample of children with average or above average motor coordination scores, matched for age, gender and intellectual ability.

It is currently not understood whether EFs in children with DCD or poor motor skills follow a developmental trajectory similar to that of their typically-developing peers, who demonstrate continued improvement in EF skills throughout middle childhood and adolescence[10]. Importantly, different EF constructs mature at different ages[11], and some seem to reach adult levels between 8-12 years[12]. A longitudinal perspective reflecting developmental change in later childhood is essential to better understand the nature of EF difficulties in children with motor impairments.

The current study is a follow-up of previous research conducted by Leonard and colleagues[13]. They recruited children of between 7-11 years by screening for movement difficulties, as well as through clinical diagnoses of DCD. Two groups of children with poor motor skills, namely a DCD group and a motor difficulty (MD) group, were compared separately with a group of typically developing (TD) children. A comprehensive EF assessment battery was administered including parallel verbal and non-verbal measures in five EF domains. The battery included measures of executive-loaded working memory (ELWM; concurrently storing and processing information), response inhibition (suppressing unhelpful, yet automatic, prepotent responses), and cognitive flexibility (switching flexibly between strategies or tasks in response to feedback). Although these three domains are identified as ‘core’ EF skills[14], a three-factor model is not as strong when applied to children, for whom a broader set of five factors may be more appropriate[15]. Therefore, measures of planning (strategically organising a sequence of actions) and fluency (generating responses in response to instruction), which have previously been used in populations with neurodevelopmental disorders[16,17] were also included in the battery. Leonard and colleagues[13] reported that both the MD and DCD groups performed significantly more poorly than TD children on *nonverbal* tests of ELWM, inhibition and fluency. There were no reported differences in performance on switching tasks, but the MD group scored significantly below TD children on the task measuring nonverbal planning abilities. Critically, no differences in performance were found on any *verbal* EF tasks.

Two years later these children were followed up with the same EF assessment battery, and these data are presented here to provide a longitudinal perspective on EF in children with poor motor skills (DCD and MD). Three research questions were put forward: RQ1) Do children with poor motor skills show persistent EF difficulties at each time point compared to TD children? RQ2) Do children with poor motor skills demonstrate gains in EF? RQ3) If so, how do these gains compare to those of TD children?

Based on the original study findings[13], it was expected that children with DCD and MD would demonstrate difficulties in *nonverbal* EF tasks compared to TD children, and that these difficulties would be evident at both time points. It was predicted that at least some gains in EF performance would be apparent for both groups, but that these may vary between EF domains, as well as between verbal versus nonverbal task types.

Method

Participants

Ethical approval was obtained from the Language and Communication Science Proportionate Review Board at City, University of London. Parents of children who participated in the original study[13] were then approached. Informed consent was obtained from 56 parents and their children (61.5 % of the original sample) to take part in this follow-up study.

At Time 1, participants with DCD were recruited on the basis of an existing diagnosis from a qualified professional, which was corroborated by the research team using the Movement Assessment Battery for Children (2nd ed.; MABC-2)[18] and Checklist, along with parent reports and a standardised IQ assessment, the British Abilities Scales 3rd Edition (BAS-3)[19]. A normative school sample was also assessed with the MABC-2. Children with scores at or below the 16th percentile were identified as having motor difficulties (MD group) and those scoring at or above the 25th percentile were included in the TD group. Any child scoring more than two standard deviations below the mean on the BAS-3 was excluded, as were any children in the DCD group with additional diagnoses of attention-deficit hyperactivity disorder or autism spectrum disorder, or any medical condition. Parents reported no diagnoses for any child in the TD and MD groups.

At Time 2 children were assigned to their original groups: TD (*n*=20), DCD (*n*=19) and MD (*n*=17). However, to confirm group membership and suitability for the study, participants were re-assessed on motor and cognitive ability. Five children were excluded from the sample because they no longer met criteria for their original group (2 DCD, 3 TD; see Supplementary Materials for further details). The final sample, therefore, included 51 children, 17 in each group (25 males; mean age: 8.9 years, SD: 1.1 years, range: 7.20–11.9). Background characteristics are presented for each group in Table 1, together with group comparisons on these measures.

--- Table 1 about here ---

Measures

A comprehensive EF assessment battery was administered, including a verbal and a nonverbal measure for each of the following EFs: executive-loaded working memory; fluency; response inhibition; planning; and cognitive flexibility (see Table 2 for a summary, and Supplementary Materials for further details). These measures were identical to those administered at Time 1 and reported in the previous study[13].

--- Table 2 about here ---

Procedure

Children who were seen at the research lab or in their home completed the assessment on the same day or over two to three sessions of 1.5 – 2 hours. Children who were tested in their school (66% at Time 1 and 48% at Time 2) completed five or six sessions of 45 minutes – one hour each. All children were assessed individually in a quiet room and sufficient breaks were given between tasks to maintain motivation. Task order was varied to suit the child's needs and offer maximum variety.

Statistical analysis

Hierarchical multiple regressions were conducted to explore any differences in EF performance between groups at each time point. Since participants in this follow-up were a subgroup of the original sample[10], regressions were conducted at both Time 1 and Time 2 in order to compare the same subgroup of participants across time. A multiple regression approach was taken so that the group differences in age and IQ (which are reported in Table 1, and are important for EF development) could be controlled at Step 1 of each regression, before examining whether there were group differences in EF performance at Step 2 using two dummy-coded Group variables. The reference group was always TD children, (i.e., TD vs. MD; TD vs. DCD). Bonferroni corrections were applied to the final models ($p \leq .005$).

A repeated measures MANOVA was used to test for differences in EF performance between the two time points and identify whether the group variable had an impact on these differences over time. Group was entered as the between-subjects factor (3 levels) and time as the within-subjects factor (2 levels), and all EF measures were entered as dependent variables[a].

Results

The means, standard deviations and ranges of scores for each of the 10 EF measures at both time points are presented in Table 3. The data met all assumptions for the following analyses (see Supplementary Materials).

--- Table 3 about here ----

[a]Age was not included because the analyses aimed to assess EF gains over time *irrespective* of age changes. Age was taken into account in the first set of analyses by entering it into Step 1 of the hierarchical multiple regressions.

Significant group differences at each time point in EF performance (RQ1) from the multiple regression analyses are reported in the text below. Summary details of Step 2 of each regression for all EF tasks are reported in Table 4.

--- Table 4 about here ----

On the *nonverbal ELWM* task, the MD and DCD groups performed significantly more poorly than the TD group at both time points.

On the *nonverbal fluency* task the final regression model at Time 1 became a non-significant trend (p=.007) after applying Bonferroni correction, whereas at Time 2 it remained significant. The MD and DCD groups performed more poorly than the TD group at both times.

On the *nonverbal response inhibition* and *nonverbal planning* tasks there was a significant group difference between the MD and TD groups at Time 1, which was not evident at Time 2. The DCD group performed more poorly than the TD group at both time points on both tasks.

On the *verbal fluency* and *nonverbal switching* tasks no differences between the MD and TD groups were identified. The DCD group performed significantly more poorly than the TD group at both time points on both tasks[b].

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[b]Additional regression analyses were conducted to directly compare children with DCD and MD across the 10 EF measures. The two groups differed significantly in *verbal fluency* at both time points (Final model Time 1, $F(4,45)=5.49$, Adj. $R^2=.27$, $p=.001$, DCD vs. MD: $B=7.72$, $SE\ B=2.80$, $p=.008$; Final model Time 2, $F(4,46)=6.09$, Adj. $R^2=.29$, $p=.001$, DCD vs. MD: $B=7.87$, $SE\ B=3.35$, $p=.023$), and in *nonverbal switching* at both time points (Final model Time 1, $F(4,46)=9.36$, Adj. $R^2=.40$, $p<.001$, DCD vs. MD: $B=-9.60$, $SE\ B=4.37$, $p=.033$; Final model Time 2, $F(4,46)=7.10$, Adj. $R^2=.33$, $p<.001$, DCD vs. MD: $B=-8.36$, $SE\ B=3.81$, $p=.033$.

In summary, children with DCD obtained poorer scores than TD children on all nonverbal EF tasks, as well as on verbal fluency, at both time points. Children with MD at Time 1 performed more poorly than TD children in all nonverbal EF domains except switching; however, at Time 2, nonverbal planning and nonverbal inhibition differences were no longer evident and only nonverbal ELWM and nonverbal fluency differences persisted.

A repeated measures MANOVA addressed the second and third research questions investigating whether children with poor motor skills demonstrate gains in EFs and how these gains compare to those of TD children.

A significant effect of Time $F(1,45)=12.11$, $p<.001$, $\eta_p^2=.771$ was identified. Univariate tests indicated the effect of Time was significant for verbal ELWM $F(1,45)=32.42$, $p<.001$, $\eta_p^2=.419$, nonverbal ELWM $F(1,45)=11.25$, $p=.002$, $\eta_p^2=.200$, verbal fluency $F(1,45)=20.21$, $p<.001$, $\eta_p^2=.310$, nonverbal fluency $F(1,45)=34.10$, $p<.001$, $\eta_p^2=.431$, nonverbal planning $F(1,45)=6.76$, $p=.013$, $\eta_p^2=.131$, verbal switching $F(1,45)=13.12$, $p=.001$, $\eta_p^2=.226$, and nonverbal switching $F(1,45)=5.10$, $p=.029$, $\eta_p^2=.102$. The effect of time was non-significant for verbal inhibition $F(1,45)=.30$, $p=.59$, $\eta_p^2=.007$, nonverbal inhibition $F(1,45)=1.37$, $p=.25$, $\eta_p^2=.030$, and verbal planning $F(1,45)=.70$, $p=.79$, $\eta_p^2=.002$.

There was a main effect of Group $F(1,45)=3.17$, $p<.001$, $\eta_p^2=.462$. However, group differences have been assessed through the previous regression analyses and will not be discussed further.

The relevant result for RQ3 was the outcome of the interaction between Time and Group, which was non-significant $F(1,45)=.94$, $p=.54$, $\eta_p^2=.202$. Thus, EF performance changed in a similar way over time in each group.

Discussion

The current study investigated EF difficulties over two years in 7-11 year-old children with poor motor skills. As predicted, children with poor motor skills showed persistent EF difficulties at both time points, largely associated with nonverbal domains of EF. In particular, children with a diagnosis of DCD performed significantly more poorly than TD children at both time points on *all* nonverbal measures of EF, and also on verbal fluency. Children without a DCD diagnosis, but with equivalent motor difficulties (MD group), also demonstrated poorer performance at Time 1 on nonverbal EF tasks (all nonverbal EF tasks except switching). However, at Time 2 only nonverbal fluency and nonverbal ELWM difficulties persisted in this group.

Also in accordance with predictions, significant improvements over time across all three groups were detected in many EF tasks: verbal and nonverbal ELWM, fluency and switching; and nonverbal planning. The fact that performance on the VIMI task did not improve over time is consistent with studies in typical populations suggesting that the ability to inhibit a prepotent response changes rapidly in early childhood but becomes more stable with age[11], and may develop earlier than other EF domains[24]. Critically, the interaction between time and group was non-significant across the EF domains. Therefore, no differences between groups were identified in the pattern of developmental change in EF over a period of two years. This result suggests that the gap in EF performance identified in children with DCD and MD compared to TD children, tends to remain stable during middle childhood.

Findings are consistent with longitudinal studies in younger populations of children with poor motor skills[8,9]. Furthermore, the fact that mainly nonverbal EF difficulties were identified at both time points in the MD and DCD groups supports recent findings that the links between motor and cognitive brain networks may lag behind those of TD controls during childhood[25].

Although the pattern of growth in EF abilities was similar between groups, some of the difficulties encountered by children with MD at Time 1 were not evident at Time 2 (nonverbal inhibition and nonverbal planning). Therefore, it is important to clarify with further longitudinal research whether specific EF domains reach typical levels of ability at a later stage during development, or whether impairments persist into adulthood. EF difficulties may have a growing impact on everyday life and academic achievement, given that the executive load of the environment is likely to increase with age while support decreases (e.g., transition to secondary school). Understanding which factors can lead to an improvement in EF will be vital in identifying those at most risk of falling behind[3].

Children with DCD demonstrated more pervasive EF difficulties over time than children with MD. The significant differences in nonverbal switching and verbal fluency performance between the MD and DCD groups cannot be attributed to an intermediate level of motor impairment in the MD group, because the range and mean of MABC-2 scores did not differ between these two groups. Perhaps given the relatively low awareness of DCD amongst parents, teachers, and clinicians[26], children with fewer or less obvious EF difficulties may be less likely to be flagged for clinical referral, despite similar levels of motor difficulty. Children with better EF may be able to deal with everyday tasks more effectively, and require less support. However, not all children with MD may show this EF profile over time, so it is important for future research to investigate this group and help to identify those that are in need of extra support.

An important finding was that children with poor motor skills did worse than TD children largely on *nonverbal* EF tasks. This suggests that EF difficulties in children with

DCD and MD are primarily linked to their core impairments rather than to more domain general cognitive processing problems. The nonverbal EF tasks in the current study had either a motor or a visuo-spatial demand, and the strong links between areas of the brain associated with these functions and those involved in executive control goes someway to explaining the EF difficulties seen in DCD. Indeed, previous research has suggested atypical functioning of prefrontal and parietal cortices and the cerebellum[27], as well as atypical connectivity or coupling between these areas[25], in children with DCD. However, it should be noted that the DCD group also had difficulties with verbal fluency, and that everyday situations require the ability to master *both* verbal and nonverbal domains of EF simultaneously and adaptably. It remains important to focus not only on reducing nonverbal demands in everyday and school-related tasks for children with poor motor skills, but to consider the cognitive load of tasks overall in order to support these children effectively.

Although the current study was rigorous in its sampling and produced in-depth data from each child over developmental time, there are limitations that should be addressed in future research. First, the small sample size meant that more complex statistical techniques, such as multi-level modelling or a cross-sequential design, were not appropriate - hence, some more subtle group differences in age-related changes in EF ability may not have been captured. It might be expected that younger children would show a greater improvement over time than older children[10], so future research should collect larger age-stratified samples to address this issue. Second, although children with additional diagnoses were excluded from the DCD sample, subclinical symptoms could still have an impact on EF. This was tested in the original study[13], and these symptoms did not significantly predict performance for any EF measure. However, conducting further research with larger samples, including those with co-occurring disorders, will be important in order to provide a fuller picture of the individual differences in a representative clinical sample. Third, our study focused on standardised and experimental measures of EF, in which task demands are set by the experimenter and do not necessarily represent the demands of EF tasks in everyday life. More ecologically valid measures of EF assessing real-life situations and 'hot' EFs, including emotional and motivational aspects, might further contribute to understanding EF difficulties associated with poor motor skills[7].

In conclusion, children with poor motor skills, both with and without a DCD diagnosis, demonstrated a range of EF difficulties that persisted over two years. EF problems largely affected nonverbal domains and were less developmentally persistent in children with MD without a diagnosis of DCD. Both the MD and DCD groups showed significant gains in EFs over middle childhood that matched those of the TD group, indicating that EF progression over time was at the level expected.

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Table 1
Means, standard deviations (in parenthesis) and *ranges* of age and scores on motor and intellectual ability tasks in typically-developing children (TD), children screened for motor difficulties (MD) and children with a diagnosis of Developmental Coordination Disorder (DCD). One-way ANOVA Welch adjusted *F* values, degrees of freedom (in parenthesis) and effect sizes are reported for age, intellectual ability scores and motor skills.

Measure	**TD Group** (*n*=17;11 girls)	**MD group** (*n*=17; 9 girls)	**DCD group** (*n*=17; 4 girls)	**ANOVA** *Welch adjusted*
	Mean (SD) *Range*	Mean (SD) *Range*	Mean (SD) *Range*	*F*(df) η_p^2
Time1 – Chronological Age (Months)	109.14 (10.92) *90.33-128*	100.76 (7.37) *93.22-124.22*	118.82 (13.96) *97-143*	*11.91* (2,29.89)*** .320
Time2 – Chronological Age (Months)	135.01 (11.60) *116.22-157*	126.13 (6.91) *118-148*	144.18 (14.48) *121-169*	*11.97* (2,29.03)*** .306
Time1 – BAS3 General Conceptual Ability Score	108.47 (12.46) *92-138*	96.82 (17.02) *71-125*	98.88 (12.81) *78-119*	*3.50* (2,31.51)* .122
Time2 – BAS3 General Conceptual Ability Score	117.29 (17.42) *89-153*	99.47 (22.57) *70-136*	104.41 (12.08) *79-127*	*4.21* (2,30.04)* .158
Time1 – MABC-2 Percentile	58.82 (20.13) *25-95*	3.76 (2.68) *0.5-9*	5.71 (5.74) *0.1-16*	*61.08* (2,25.29)*** .823
Time2 – MABC-2 Percentile	51.06 (21) *25-84*	5.35 (4.01) *1-16*	2.22 (2.58) *0.1-9*	*46.32* (2,27.11)*** .774

Note. MABC-2 = Movement Assessment Battery for Children; BAS3 = British Abilities Scales. Children with DCD were significantly older than TD children at Time 1 (*p*=.037) and children with MD at both time points (*p*s<.001); TD children obtained significantly higher intellectual ability scores than the MD group at Time 2 (*p*=.015); TD children had higher motor ability than the DCD and MD groups at both time points (*p*s<.001).

p* ≤ .05; ** *p* ≤ .01; * *p* ≤ .001.

Table 2.
Description of tasks administered to assess Executive Functions.

EF Measured	Domain	Task	Description	Outcome Variable
Executive-Loaded Working Memory	Verbal	Listening Recall (Working Memory Test Battery for Children[20])	Participants recall the last word of a sentence after making a judgement as to whether the sentence was true or false, with the number of sentences increasing as the task continues.	Total correct trials
	Nonverbal	Odd-One-Out[21]	A nonverbal equivalent of the above task, in which participants recall the spatial location of a nonsense shape after making a judgement as to which of the shapes was the 'odd one out'.	Total correct trials
Fluency	Verbal	Verbal Fluency (D-KEFS[22])	Participants generate as many words as possible belonging to two different specific categories, within one minute.	Total correct responses
	Nonverbal	Design Fluency (D-KEFS[22])	Participants generate as many designs as possible, according to a series of particular criteria, within one minute.	Total correct responses
Inhibition	Verbal	VIMI[17] - verbal	Participants copy a word said by the experimenter, or provide another word (i.e., inhibit the copying response), depending on instructions.	Total errors
	Nonverbal	VIMI[17] - motor	Participants copy an action demonstrated by the experimenter, or provide another action (i.e., inhibit the copying response), depending on instructions.	Total errors
Planning	Verbal	Sorting (D-KEFS[22])	Participants sort two sets of six cards into two groups of three in as many ways as possible based on verbal features	Total correct verbal sorts
	Nonverbal	Sorting (D-KEFS[22])	Participants sort two sets of six cards into two groups of three in as many ways as possible based on perceptual features	Total correct perceptual sorts
Switching	Verbal	Trail Making Test (D-KEFS[22])	Participants have to draw a line between numbers and letters in sequence, switching between the two (e.g., 1-A-2-B, etc.)	Completion time switching cost
	Nonverbal	Intra/Extra Dimensional Shift (CANTAB[23])	Participants learn a rule through initial trial and error in relation to a shape and then have to switch to a different rule to continue achieving 'correct' answers.	Total errors

Table 3. Descriptive statistics for each EF measure at both time points.

EF Domain	EF measure		**TD** (*n*=17) Mean; *SD* (Range)	**MD** (*n*=17) Mean; *SD* (Range)	**DCD** (*n*=17) Mean; *SD* (Range)
Working Memory *Verbal*	WMTBC Listening Recall *Total Correct*	Time 1	14.24; *3.05* (8-21)	11.12; *3.86* (6-19)	13.88; *3.14* (10-23)
		Time 2	17.53; *4.99* (12-27)	14.35; *3.92* (8-24)	16.24; *4.09* (12-29)
Working Memory *Nonverbal*	Odd-One-Out *Total Correct*	Time 1	11.53; *3.20* (6-17)	6.88; *3.44* (3-14)	7.82; *3.19* (4-15)
		Time 2	13.18; *2.94* (7-18)	8.76; *3.31* (3-17)	9.88; *3.94* (4-16)
Fluency *Verbal*	D-KEFS Verbal Fluency *Total Correct*	Time 1	30.65;*8.08* (15-44)	26.24; *5.98* (16-39)	24.50; *7.79*[a] (3-38)
		Time 2	38.06; *9.46* (17-52)	30.41; *7.94* (18-51)	28.82; *8.83* (12-48)
Fluency *Nonverbal*	D-KEFS Design Fluency *Total Correct*	Time 1	14.76; *4.25* (7-22)	10.35; *4.44* (1-20)	12.12; *3.71* (5-21)
		Time 2	19.65; *5.56* (10-28)	14.24; *3.56* (10-22)	15.12; *4.48* (9-23)
Response Inhibition *Verbal*	VIMI Verbal *Total Errors*	Time 1	9.47; *6.50* (0-23)	12.35; *6.65* (5-29)	16.53; *9.96* (4-36)
		Time 2	8.53; *5.99* (0-24)	12.82; *6.52* (5-28)	14.82; *6.55* (6-27)
Response Inhibition *Nonverbal*	VIMI Motor *Total Errors*	Time 1	28.94; *14.17* (3-51)	43.53; *12.39* (21-61)	48.82; *16.62* (21-74)
		Time 2	26.71; *11.12* (8-48)	40.53; *13.85* (11-64)	43.71; *15.83* (14-71)
Planning *Verbal*	D-KEFS Verbal Sorting *Total Correct*	Time 1	2.24; *.97* (1-4)	2.00; *1.06* (0-3)	2.65; *1.06* (1-4)
		Time 2	2.65; *1.06* (1-4)	2.41; *1.0* (1-4)	2.35; *1.17* (0-4)
Planning *Nonverbal*	D-KEFS Perceptual Sorting *Total Correct*	Time 1	7.12; *1.65* (3-9)	4.41; *2.45* (0-7)	4.47; *2.24* (0-8)
		Time 2	7.47; *1.18* (6-10)	4.88; *2.74* (0-9)	6.06; *1.39* (3-9)
Cognitive Flexibility *Verbal*	D-KEFS Trail Making *Switching cost (sec.)*	Time 1	34.65; *41.16* (-8 – 162)	86.60; *87.09*[b] (-31 – 244)	24.81; *47.75*[c] (-101 – 102)
		Time 2	16.35; 33.*94* (-16 – 128)	22.88; *32.14* (-25 – 84)	9.18; *40.77* (-41 – 121)
Cognitive Flexibility *Nonverbal*	CANTAB IEDS *Total Errors*	Time 1	20.29; *12.90* (8-42)	29.53; *14.92* (8-56)	29.53; *11.59* (8-51)
		Time 2	16.94; *8.98* (7-35)	24.82; *10.76* (9-38)	23.35; *12.61* (9-54)

Note. EF=Executive Function; WMBTC=Working Memory Test Battery for Children; D-KEFS=Delis-Kaplan Executive Function System; VIMI=Verbal Inhibition, Motor Inhibition; CANTAB=Cambridge Neuropsychological Test Automated Battery; IEDS=Intra-/Extra-Dimensional Shift.

[a]1 Missing data point; [b]2 missing data points; [c]1 missing data point.

Table 4. Summary details of step 2 of the hierarchical multiple regression analyses predicting performance in all executive function measures.

EF Domain		Final Model F(df) Adj. R^2	Details of Step 2 for each regression	Age	IQ	TD Vs. MD	TD Vs. DCD	ΔR^2 Step 2
ELWM Verbal	Time 1	10.47(4,46) **.43***** p<.001	β Unst.β SE	.48*** .13 (.04) p=.001	.37** .09 (.03) p=.002	-.13 -.99 (1.01) p=.33	-.11 -.83 (1.05) p=.43	.01 p=.56
	Time 2	8.24(4,46) **.37***** p<.001	β Unst.β SE	.57*** .19 (.05) p<.001	.42*** .10 (.03) p=.001	.02 .218 (1.40) p=.87	-.19 -1.81 (1.33) p=.18	.03 p=.31
ELWM Nonverbal	Time 1	7.90(4,46) **.36***** p<.001	β Unst.β SE	.38** .11 (.04) p=.010	.13 .03 (.03) p=.30	-.42** -3.37 (1.14) p=.005	-.57*** -4.51 (1.18) p<.001	.22*** p=.001
	Time 2	6.36(4,46) **.30***** p<.001	β Unst.β SE	.16 .05 (.04) p=.27	.36** .07 (.03) p=.009	-.34* -2.74 (1.27) p=.036	-.35* -2.81 (1.21) p=.024	.10* p=.035
Fluency Verbal	Time 1	6.25(4,45) **.27***** p=.001	β Unst.β SE	.56*** .53 (.14) p<.001	.17 .14 (.11) p=.178	-.09 -2.83 (4.11) p=.560	-.55*** -2.55 (4.26) p=.001	.20** p=.003
	Time 2	6.81(4,46) **.29***** p=.001	β Unst.β SE	.44** .10 (.19) p=.003	.22 .06 (.12) p=.140	-.14 -3.2 (5.84) p=.168	-.54*** -3.0 (5.54) p=.001	.19** p=.003
Fluency Nonverbal	Time 1	4.04(4,46) .20** p=.007	β Unst.β SE	.29 .10 (.05) p=.085	.16 .05 (.04) p=.401	-.33* -3.04 (1.49) p=.047	-.34* -3.20 (1.55) p=.044	.10† p=.058
	Time 2	5.28(4,46) **.26***** p=.001	β Unst.β SE	.36* .14 (.06) p=.018	.12 .03 (.04) p=.380	-.34* -3.63 (1.74) p=.042	-.50** -5.39 (1.65) p=.002	.17** p=.006
Response Inhibition Verbal	Time 1	1.66(4,46) .05 p=.175	β Unst.β SE	-.02 -.01 (.11) p=.898	-.01 -.01 (.08) p=.965	.16 2.72 (3.01) p=.370	.41* 7.15 (3.06) p=.024	.10 p=.076
	Time 2	2.96(4,46) .14* p=.029	β Unst.β SE	-.22 -.11 (.08) p=.165	-.16 -.06 (.05) p=.265	.16 2.24 (2.48) p=.373	.46** 6.54 (2.34) p=.008	.14* p=.027
Response Inhibition Nonverbal	Time 1	4.60(4,46) **.22**** p=.003	β Unst.β SE	-.14 -.18 (.19) p=.365	-.08 -.09 (.15) p=.547	.35* 12.04 (5.46) p=.032	.59*** 20.59 (5.56) p=.001	.22** p=.002

	Time 2	*4.86*(4,46) **.24**** *p*=.002	β *Unst.β* *SE*	-.29† *-.34* *(.17)* *p*=.055	-.09 *-.07* *(.11)* *p*=.515	.29 *9.52* *(5.30)* *p*=.079	.59*** *19.05* *(5.01)* *p*<.001	.22** *p*=.002
Planning Verbal	Time 1	*2.04*(4,46) .08 *p*=.104	β *Unst.β* *SE*	.22 *.02* *(.01)* *p*=.194	.21 *.02* *(.01)* *p*=.150	.04 *.08* *(.38)* *p*=.824	.18 *.39* *(.39)* *p*=.321	.02 *p*=.596
	Time 2	*.82*(4,46) -.02 *p*=.525	β *Unst.β* *SE*	-.21 *-.02* *(.01)* *p*=.221	-.18 *-.01* *(.01)* *p*=.267	.25 *-.56* *(.42)* *p*=.189	.12 *-.27* *(.42)* *p*=.498	.04 *p*=.414
Planning Nonverbal	Time 1	*7.79*(4,46) **.35***** *p*<.001	β *Unst.β* *SE*	.11 *.02* *(.03)* *p*=.441	.37** .06 *(.02)* *p*=.005	-.36* *-1.84* *(.74)* *p*=.017	-.44** *-2.27* *(.76)* *p*=.005	.14** *p*=.007
	Time 2	*13.84*(4,46) **.51***** *p*<.001	β *Unst.β* *SE*	.34** *.06* *(.02)* *p*=.006	.54*** .06 *(.01)* *p*<001.	-.23 *-1.02* *(.59)* *p*=.094	-.25† *-1.13* *(.56)* *p*=.051	.05 *p*=.094
Cognitive Flexibility Verbal	Time 1	*4.15*(4,43) .22** *p*=.006	β *Unst.β* *SE*	-.18 *-.90* *(.77)* *p*=.249	-.29* -1.32 *(.62)* *p*=.039	.22 *31.02* *(22.25)* *p*=.170	-.08 *-11.59* *(22.52)* *p*=.610	.05 *p*=.216
	Time 2	1.48(4,46) .04 *p*=.223	β *Unst.β* *SE*	-.27 *-.71* *(.44)* *p*=.115	-.24 -.44 *(.28)* *p*=.123	-.10 *-7.66* *(13.69)* *p*=.579	-.09 *-6.40* *(13.03)* *p*=.625	.01 *p*=.822
Cognitive Flexibility Nonverbal	Time 1	*8.84*(4,46) **.39***** *p*<.001	β *Unst.β* *SE*	-.45** *-.47* *(.14)* *p*=.002	-.40** *-.37* *(.11)* *p*=.002	.03 *.83* *(4.02)* *p*=.836	.34* *9.85* *(4.09)* *p*=.020	.08* *p*=.048
	Time 2	*7.10*(4,46) **.33***** *p*<.001	β *Unst.β* *SE*	-.63*** *-.53* *(.12)* *p*<.001	-.17 *-.10* *(.06)* *p*=.194	.06 *1.49* *(3.61)* *p*=.682	.42** *9.85* *(3.43)* *p*=.006	.12* *p*=.016

Note. For each regression the final model *F* values, degrees of freedom in parentheses, and adjusted R^2 are presented, along with the change in R^2 in Step 2 of the model. Standardized beta values, *unstandardized coefficients*, and *standard errors* (in parentheses) are reported for each predictor variable. Significant final regression models after Bonferroni corrections ($p \leq .005$) are indicated in boldface. ELWM: executive-loaded working memory. 1 missing data point for verbal fluency measures at Time 1 (DCD group). 3 missing data points for verbal cognitive flexibility measures at Time 1 (2 MD, 1 DCD).

$^{*}p \leq .05$; $^{**}p \leq .01$; $^{***}p \leq .001$; $^{\dagger}p \leq .06$ non-significant trend.