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The role of inattention and hyperactivity/impulsivity in the fine motor coordination in children with ADHD☆

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ABSTRACT

Objective: Deficits in fine motor coordination have been suggested to be associated with Attention-Deficit/Hyperactivity Disorder (ADHD). However, despite the negative impact of poor fine motor skills on academic achievement, researchers have paid little attention to this problem. The aim of this study was to explore the relationship between ADHD dimensions and fine motor performance.

Method: Participants were 43 children with a diagnosis of ADHD aged between 7 and 14 years ($M = 9.61$; 81% male) and 42 typically developing (TP) children in the same age range ($M = 10.76$; 75.2% male).

Results: Children with ADHD performed worse than TP on all tasks ($\delta^{\text{Fine\_motor\_tasks,}}$ −0.19 to −0.44). After controlling for age and ADHD-HY (hyperactivity/impulsivity), higher scores on ADHD-IN (inattentiveness) predicted a larger number of mistakes among all psychomotricity tasks and conditions (β 0.39–0.58, $ps < 0.05$).

Conclusion: The ADHD group showed poorer fine motor performance than controls across all fine motor coordination tasks. However, lower performance (more mistakes), was related to the inattention dimension but not to the hyperactivity/impulsivity dimensions. Authors recommend including training and enhancement of the fine motor skills for more comprehensive ADHD treatment.

What this paper adds?

1. This study provides empirical evidence for the hypothesis that children with ADHD have a poorer fine motor performance than children with typical development.
2. The handwriting of the ADHD children is characterized by a less accurate line drawing, meaning more mistakes.
3. Our results suggest that the fine motor coordination is related to the inattention dimension but not to the hyperactivity/impulsivity dimensions. Therefore, these difficulties would affect both clinical subtypes of ADHD (predominantly inattentive and combined presentations)
4. Our study provides empirical evidence of why it is important to develop interventions that improve handwriting performance in children with ADHD.

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1. Introduction

Fine motor writing skills are becoming recognized as an important factor associated with later academic success (Dinehart & Manfra, 2013; Grissmer, Grimm, & Aiyer, 2010) both in kindergarten (Luo, Jose, Huntsinger, & Piggot, 2007) and first grade (Son & Meisels, 2006). Notably, poor handwriting ability during the school age years often has far-reaching negative effects on academic success (Feder & Majnemer, 2007). Difficulties in graphomotor skills tend to cluster together with learning, attention and processing speed weakness, and these indicators show a high degree of accuracy in predicting the presence or absence of learning disability in reading, math and written expression (Mayes & Calhoun, 2007). This observation should not come as a surprise since a large part of the daily activities in the classroom require fine motor skills (McHale & Cermak, 1992), which could be the case for children with Attention-Deficit/Hyperactivity Disorder (hereafter ADHD) (Barkley, 2015).

Although the critical feature of ADHD is a persistent pattern of inattention and/or hyperactivity/impulsivity behavior, the disorder is heterogeneous at multiple levels (Wåhlstedt, Thorell, & Bohlin, 2009). ADHD-related difficulties extend beyond primary diagnostic symptoms of inattention (and often hyperactivity/impulsiveness) but also affect other functional skills for daily living, for example, problem solving, emotional/motivational self-regulation, deficits in motor coordination, or time management (Fenollar-Cortés & Fuentes, 2016). Most of these difficulties may have a direct or indirect negative effect on academic performance. Long-term academic outcomes are among those most strongly affected by ADHD (Arnold, Hodgkins, Kahle, Madhoo, & Kewley, 2015; Sayal, Washbrook, & Propper, 2015).

1.1. Deficits in fine motor coordination

Deficits in fine motor coordination have been suggested to be associated with ADHD (Goulardins, Marques, Casella, Nascimento, & Oliveira, 2013), affecting up to 30–50% of ADHD cases (Fliers et al., 2008). Children with ADHD performed worse than controls in handwriting quality and quantity, as characterized by illegible writing products and slow execution (Shen, Lee, & Chen, 2012).

Despite the negative impact of poor fine motor skills on academic achievement, researchers have paid little attention to this problem, and it has usually been excluded from the ADHD assessment protocols (Fliers et al., 2008; Fliers et al., 2010). This issue is particularly problematic, especially when considering that pharmacological interventions do not appear to produce any remarkable improvement in the motor coordination of ADHD individuals (e.g., Bart, Podoly, & Bar-Haim, 2010; but see Rosenblum, Epsztein, & Josman, 2009). Furthermore, Tucha and Lange (2001) concluded that the kinematic aspects of handwriting performance in children with ADHD were adversely affected by stimulant therapy. Thus, further research on the relationship between ADHD and fine motor abilities is required. For example, the underlying mechanisms of the association between ADHD and motor coordination problems remain unclear (Shen et al., 2012).

It is also of special relevance to investigate how some task components may modulate fine motor performance in ADHD children (Langmaid, Papadopoulos, Johnson, Phillips, & Rinehart, 2016). The study of the nature and consequences of difficulties in fine motor coordination is particularly appropriate to enhance academic success and self-competency in children with ADHD (Brossard-Racine, Majnemer, Shevell, & Snider, 2008).

1.2. The current study

There is a broad consensus for the need to explore the relationship between ADHD symptom dimensions and specific domains of impairment. The distinction between inattention and hyperactivity-impulsivity could provide important clinical information (Willcutt et al., 2012). However, the relationship between ADHD dimensions and fine motor coordination has been poorly studied and has often been addressed in relation to comorbid developmental coordination disorder (Noda et al., 2013).

The aim of this study was to explore the relationship between ADHD dimensions (i.e., inattentiveness and hyperactivity/impulsivity) and fine motor performance as measured by accuracy, fluency and speed, using three repeated paper and pencil measurements. The purpose of the current study was to examine (i) differences in the fine psychomotricity performance for accuracy, fluency and speed between children with ADHD and children without ADHD and (ii) the unique effects of inattention and hyperactivity/impulsivity dimensions on psychomotricity tasks. We hypothesized that ADHD children would show poorer fine psychomotricity performance than controls in all tasks. We also hypothesized that ADHD-inattentiveness would be negatively related to accuracy and fluency, while hyperactivity/impulsivity would be positively related to execution speed.

2. Method

2.1. Participants

Participants were forty-three children with a diagnosis of ADHD aged between 7 and 14 years ($M = 9.61$; $SD = 2.20$; 81% male) and forty-two typically developing (TP) children in the same age range ($M = 10.76$; $SD = 2.56$; 75.2% male). ADHD cases were recruited from children's mental health centers. Exclusion criteria for the clinical group included a comorbid diagnosis of autism, epilepsy, psychotic disorders, intellectual disability, brain disorders or any medical disorder associated with externalizing behaviors that may mimic ADHD symptoms. ADHD participants were required to (i) have been diagnosed with ADHD by a mental health professional prior to the study and (ii) show inattention symptoms to both parents and teachers (ADHD Rating Scale-IV) at the time of the study. TP children were recruited from schools in the metropolitan area. Regarding medication, 46.5% of ADHD participants were taking methylphenidate. None of the participants were taking atomoxetine.

2.2. Measures

The outcome measures for the study are organized in terms of measures of clinical scales and fine motor coordination tasks.

2.2.1. Clinical scales

The *ADHD Rating Scale-IV* was used (ADHD RS-IV; DuPaul, Power, Anastopoulos, & Reid, 1998; Spanish version, Servera & Cardo, 2007). Mothers and teachers rated the occurrence of the nine ADHD-IN (inattentive) and ADHD-HI (hyperactive-impulsive) symptoms on the ADHD RS-IV for the past 6 months on a 4-point scale (0 = never or rarely; 1 = sometimes; 2 = often; 3 = very often). This scale has recently been validated for DSM 5 criteria for ADHD and has once more showed good psychometric properties (DuPaul et al., 2015). Cronbach's alphas for the ADHD-I and ADHD-HI subscales for parents were 0.96 and 0.94, respectively, with values of 0.96 and 0.97 for teachers, respectively.

The *ADHD Concomitant Difficulties Scale* (ADHD-CDS; Fenollar-Cortés & Fuentes, 2016). Parents rated the occurrence of 13 CEHD-related difficulties for the past 6 months on a 4-point scale (0 = "not true"; 1 = "a little true"; 2 = "quite true"; 3 = "completely true"). The ADHD-CDS assesses the presence of some of the most important comorbidities that are usually associated with ADHD such as emotional/motivational management, fine motor coordination, problem-solving/management of time, disruptive behavior, sleep habits, academic achievement and quality of life. Cronbach's alpha was 0.95. For the current study, we took into consideration the third (handwriting performance) and fourth (handicrafts skills) items.

2.2.2. Fine psychomotor tasks

Three tasks requiring psychomotor effort were designed:

2.2.2.1. The spiral task. A series of 163 dots with a 0.2 cm thickness and separated by 1 cm suggested a spiral figure. Participants were asked to join the dots together from the outside to the center of the figure. The dependent variables included the following: number of dots missed by inaccuracy (labeled as "spiral mistakes") and number of times that the pencil was lifted from the paper (labeled as "spiral pencil").

2.2.2.2. The flower task. A series of 295 dots with a 0.1 cm thickness and separated by a distance of 0.5 cm. The figure resembles a flower and is composed by combining the same figure five times with different orientations. Participants were allowed to start from any dot. The task was performed initially without timing and with two dependent variables: number of dots missed by inaccuracy (labeled as "flower mistakes") and number of times that the pencil was lifted from the paper (labeled as "flower pencil"). The task was then repeated measuring both dependent variables but was timed on this occasion (adding "Time" to the labels and adding the variable "flower time").

2.2.2.3. The series task. This task included two series of different figures that participants were asked to reproduce while maintaining the proportions as closely as possible. The first series consisted of a row of 1.7 cm squares with a repeated pattern of vertical lines followed by a horizontal line that alternates from side to side of the first in a shape similar to castle battlements. The second series consisted of triangles with two sides of 2 cm and a shorted 1.63 cm side that was not drawn with a height of 2.08 cm. Dependent variables were collected for each of this series and were related to the number of mistakes ("series_X_mistakes" being "X" the figure represented in the series), variations larger than 5 mm regarding the model figure ("series_X_varia") and number of figures reproduced in the series ("series_X_number").

2.3. Procedure

The tasks were performed in hypo-stimulating environments under the supervision of a member of the research team. Both the supervision of the tasks and their later correction were under blind conditions. Tasks were presented in the same order using one sheet per task and blocking the manipulation of the sheet by affixing it to the surface. The instructions did not allow erasing, corrections, the use of instruments or abandoning the chair during the task. One of the instructions was not to lift the pencil from the paper when starting with each figure. Children with ADHD were off stimulant medication for at least 24 h before testing.

In addition, parents and teachers were informed that study participation was voluntary and confidential. All parents who met the inclusion criteria agreed to participate gave written informed consent, and none of the teachers declined participation. The Ethic Committee of the University of Murcia approved the protocol for the study.

2.4. Analytic strategy

The analysis had two stages according to the following sequence. First, differences between fine motor coordination from the clinical and control groups were computed using nonparametric tests. The Mann-Whitney *U* test was used to compare the control group vs. the ADHD group. We checked whether both groups differed in either age or gender. Cliff's Delta was calculated as an estimate of the effect size. Second, the ADHD dimensions (i.e., inattentiveness (ADHD-IN) and hyperactivity/impulsivity (ADHD-HY)

Table 1
Scores comparison between clinical/control groups (Mann–Whitney *U* test).

		Control group	ADHD group	δ[a]
Spiral				
	Spiral_mistakes	6.47(5.86)	17.03(16.17)	−0.44[***]
	Spiral_pencil	1.00(1.51)	1.36(1.79)	n.s.[b]
Flower				
	Flower_mistakes	44.45(27.47)	65.14(33.12)	−0.29[*]
	Flower_pencil	2.08(2.69)	2.64(2.55)	n.s.
	Flower_mistakes_time	50.82(29.81)	77.39(41.75)	−0.43[***]
	Flower_pencil_time	2.00(2.57)	1.69(2.15)	n.s.
Series				
	Series_row_mistakes	0.55(0.83)	1.92(2.09)	−0.33[**]
	Series_row_varia	2.37(2.82)	1.92(2.57)	n.s.
	Series_row_number	4.55(0.98)	4.28(0.94)	n.s.
	Series_triangles_mistakes	0.61(1.20)	1.58(2.63)	−0.19[*]
	Series_ triangles _varia	2.66(3.51)	2.67(3.62)	n.s.
	Series_ triangles _number	9.55(2.48)	8.89(2.42)	n.s.
Time		55.05(18.52)	45.86(22.57)	n.s.

[a] Cliff's Delta for effect size (non-parametric).
[b] n.s. = not significant.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

scores on the ADHD-RS-IV for parents and teachers) and fine motor task scores were computed and used to estimate correlations. We also computed unique effects among ADHD-IN, ADHD-HY, and fine motor task scores (partial correlations and multiple regressions analysis, respectively).

3. Results

3.1. Fine psychomotricity performance comparison between groups

With the exception of the Series task variables, the remaining dependent variables were normally distributed (Kolmogorov-Smirnov test $p > 0.05$) and showed similar variance in ADHD children and controls (Levene's test $p > 0.05$). In such cases, parametric or non-parametric analyses were applied accordingly. Neither age nor gender differences between groups were found.

A Mann–Whitney *U* test was conducted to assess the performance differences between the control and the clinical groups (Table 1). Cliff's delta was used to estimate the effect sizes (an effect size of 1.0 or −1.0 indicates the absence of overlap between the two groups, whereas an effect size of 0 indicates that the group distributions are equivalent). The magnitude is assessed using the thresholds provided in Romano, Kromrey, Coraggio, and Skowronek (2006); that is, $0.147 < \delta < 0.33$ "small", $0.33 < \delta < 0.474$ "medium", and $\delta > 0.474$ "large". Planned contrasts revealed that children with ADHD performed worse than controls on all tasks ($\delta^{\text{Spiral\_mistakes}} = -0.44$; $\delta^{\text{Flower\_mistakes}} = -0.29$; $\delta^{\text{Flower\_mistakes\_time}} = -0.43$; $\delta^{\text{series\_row\_mistakes}} = -0.33$; $\delta^{\text{series\_triangle\_mistakes}} = -0.19$). In all cases, effect sizes of significant differences were small-to-medium. However, there were no differences between groups for the number of times that the pencil was lifted from the paper ($ps > 0.05$). There were also no statistically significant differences between groups in the time required to complete the tasks. Thus, the ADHD group showed poorer fine motor performance than controls across all fine motor coordination tasks; however, this group was neither faster nor lifted the pencil from the paper more times than the controls.

Regarding the parent's reports about the handwriting quality and handicrafts of their children, parents indicated that their child's handwriting was worse in the ADHD group ($Mdn = 3$) than the controls ($Mdn = 0$), $U = 107.0$, $p < 0.001$, $\delta = -0.88$. Similarly, child's handicrafts were worse for ADHD ($Mdn = 3$) than for controls ($Mdn = 0$), $U = 287.5$, $p < 0.001$, $\delta = -0.67$. In both cases, the effect sizes were large.

Partial Correlations among Fine Task Scores and ADHD dimensions

All dependent variables were significantly correlated with the child's age ($r = -0.17$ to -0.42, $ps < 0.05$; $r = -0.17$ to -0.30, $ps < 0.05$). Therefore, partial correlations were conducted (age-adjusted). A correlation of 0.10 is considered a small effect, a correlation of 0.30 is considered a medium effect, and a correlation of 0.50 is considered a large effect (Cohen, 1988).

The dependent variables were significantly correlated among fine motor tasks. That is, the "mistake" variables (i.e., number of dots missed by inaccuracy) were significantly correlated ($r = 0.72$ to 0.76; $ps < 0.001$). The correlation for the number of times that the pencil was lifted from the paper was lower but statistically significant ($r = 0.21$ to 0.52; $ps < 0.05$). Correlation between "series_spiral_mistakes" and "series_triangle_mistakes" was large and statistically significant ($r = 0.51$; $p < 0.001$).

ADHD symptoms were significantly correlated with the number of mistakes both for parents and teachers (Table 2). Higher scores for the ADHD-IN and ADHD-HY symptoms were associated with significantly more mistakes for the spiral and flower tasks ($r = 0.26$ to 0.43; $ps < 0.05$). In contrast, scores on the ADHD dimensions were not significantly related to the number of times that the pencil

Table 2
First-Order Partial Correlations Among Fine Psychomotricity Scores and ADHD symptoms.

		Parents		Teachers	
		ADHD-IN	ADHD-HY	ADHD-IN	ADHD-HY
Spiral					
	Spiral_mistakes	**0.38*****	**0.29***	**0.43*****	**0.40*****
	Spiral_pencil	0.16	0.12	0.01	0.03
Flower					
	Flower_mistakes	**0.36*****	**0.26***	**0.33****	**0.29***
	Flower_pencil	0.18	0.20	0.10	0.16
	Flower_mistakes_time	**0.35****	**0.24***	**0.32****	**0.24***
	Flower_pencil_time	−0.03	0.02	−0.04	0.10
Series					
	Series_row_mistakes	**0.34****	0.13	**0.52*****	**0.37*****
	Series_row_varia	−0.11	−0.12	−0.02	−0.05
	Series_row_number	−0.17	−0.19	−0.06	−0.20
	Series_triangles_mistakes	0.18	0.02	.32**	**0.27***
	Series_ triangles _varia	−0.05	−0.16	−0.04	−0.09
	Series_ triangles _number	−0.18	−0.13	−0.18	−0.20
Time		−0.21	**−0.26***	**−0.25***	−0.22

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$

was lifted from the paper. Both rows and triangles mistakes were medium to highly significantly correlated with ADHD symptoms as rated by teachers ($r = 0.27$ to 0.52; $ps < 0.05$). No correlations were found between parents-rated ADHD symptoms. Regarding series mistakes, we found only a significant correlation between ADHD-IN and "series_row_mistakes" ($r = 0.34$; $p < 0.01$). Time was only slightly correlated with parents-rated ADHD-HY and teacher-rated ADHD-IN.

3.2. Unique effects of inattention and hyperactivity/impulsivity dimensions on psychomotricity tasks

The unique relationships between the ADHD-IN, ADHD-HY dimensions and the adjustment domains were determined by the regression of the outcomes on the two predictors simultaneously (i.e., a single regression analysis). Age was also included as an outcome. This analysis was conducted using SPSS (version 23.0; SPSS, IBM Corp.), with results (standardized partial regression coefficients and their standard errors) summarized in Table 3.

After controlling for age and ADHD-HY, higher scores on ADHD-IN (parents) predicted a larger number of mistakes among all

Table 3
Unique Effects of Inattention, Hyperactivity/Impulsivity Dimensions on Psychomotricity Tasks (Age adjusted).

		Parents				Teachers			
		ADHD-IN		ADHD-HY		ADHD-IN		ADHD-HY	
		β	SE	β	SE	β	SE	β	SE
Spiral									
	Spiral_mistakes	**0.43***	0.25	−0.09	0.29	0.27	0.23	0.16	0.25
	Spiral_pencil	0.01	0.04	0.12	−0.09	0.18	0.04	−0.20	0.05
Flower									
	Flower_mistakes	**0.39***	0.59	−0.11	0.69	0.10	0.56	0.22	0.61
	Flower_pencil	0.06	0.06	0.12	0.07	−0.18	0.06	0.33	0.06
	Flower_mistakes_time	**0.52****	0.74	−0.17	0.86	**0.45***	0.73	−0.13	0.79
	Flower_pencil_time	−0.15	0.05	0.17	0.06	−0.32	0.05	**0.41***	0.11
Series									
	Series_row_mistakes	**0.58****	0.04	−0.31	0.05	**0.38***	0.04	0.11	0.04
	Series_row_varia	0.08	0.06	−0.09	0.07	−0.01	0.07	0.10	0.07
	Series_row_number	0.07	0.02	−0.10	0.03	0.18	0.02	−0.14	0.03
	Series_triangles_mistakes	**0.46***	0.04	−0.33	0.05	0.27	0.04	0.07	0.04
	Series_ triangles _varia	0.27	0.07	−0.31	0.09	0.10	0.07	−0.17	0.08
	Series_triangles _number	−0.15	0.05	−0.26	0.11	0.01	0.5	−0.17	0.05
Time		−0.01	0.42	−0.12	0.49	−0.24	0.43	0.08	0.46

* $p < 0.05$.
** $p < 0.01$.

psychomotricity tasks and conditions ($ps < 0.05$). However, in contrast with the previous correlation results, after controlling for age and ADHD-IN, no associations were found between ADHD-HY and the number of mistakes for any of the tasks. For teachers, the results were different only when associated ADHD-IN with both "flower mistakes time" and "series_row_mistakes" ($ps < 0.05$). Higher ADHD-IN scores predicted a higher number of mistakes in those variables.

4. Discussion

According to previous studies and our current findings, children diagnosed with ADHD show poorer handwriting ability on average than controls. Children with ADHD would be less accurate in line tracing than controls; however, this imprecision is not related to the hyperactivity/impulsivity dimension but is instead related to the inattention dimension. These results contrast with those reported by Noda et al. (2013). The authors found that inattention and fine motor skills were related to writing difficulties. Whereas inattention predicted both spelling accuracy (which matches with our results) and handwriting fluency, hyperactive/impulsive behavior predicted just handwriting fluency. However, the participants of Noda et al. (2013) were not children with an ADHD diagnosis. In addition, most of the fine motor tasks that were used necessarily implied other cognitive areas such as working memory, particularly visuospatial working memory. Previous meta-analysis studies have concluded that visuospatial working memory is clearly affected in ADHD (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005; Willcutt et al., 2005; Willcutt et al., 2012); therefore, working memory involvement could have biased the Noda et al.'s results. To avoid such a contamination, in the present study we used just fine motor tasks that would not involve other potentially weak ADHD areas such as visuospatial working memory or reading performance.

The present results are consistent with previous studies that found no fine motor differences between ADHD children with and without hyperactive behavior (Resta & Eliot, 1994). Thus contrary to inattention, hyperactivity/impulsivity does not seem to be a good predictor of fine motor performance in ADHD children (Fliers et al., 2008).

The fact that fine motor difficulties appear only in inattentive ADHD children highlights the role of attention in handwriting abilities. Attentional resources may be crucial in the process of acquiring automated handwriting abilities, so that inattentive children would be unable to dedicate enough attentional resources to the processes involved in handwriting. As a consequence, inattentive ADHD children showed a deficit in handwriting quality compared to non-ADHD children or hyperactive/impulsive ADHD children.

Some studies that have addressed the effects of Methylphenidate (MPH) on fine motor performance in ADHD children provide empirical support to the attentional resources hypothesis. For example, Tucha and Lange (2001) concluded that the positive effects of methylphenidate enabled ADHD children to focus attention on their handwriting up to show comparable performance to non-ADHD children. However, this improvement in handwriting quality occurred at the expense of fluency (speed and acceleration) and therefore affected the automatization of the processes involved in handwriting. Similarly, other studies argued that MPH improved only the attentional components involved in movement and motor planning (e.g., Bart et al., 2010; Flapper & Schoemaker 2008). Thus, we conclude that the poor fine motor performance exhibited by ADHD children is a consequence of their inattentiveness, and not a motor problem *per se*.

4.1. Fine motor intervention in school settings

Teachers often do not have the required resources (nor specific materials or exhaustive knowledge) for intervention in class with children with ADHD. In addition, special educators often neglect handwriting to focus on other areas of the curriculum (Berninger et al., 2006). However, teachers and school professionals are widely accepted to be crucial in implementing successful behavioral, academic, and/or self-regulation interventions (DuPaul, Gormley, & Laracy, 2014).

The use of early education curricula that includes fine motor writing and copying may be an effective method for improving learning during the early school years (Dinehart, 2015; Dinehart & Manfra, 2013). Improving the fine motor skill could lead to enhancements in other relevant academic areas. Pitchford, Papini, Outhwaite, and Gulliford (2016) recently concluded that fine motor integration remained a significant predictor of math ability even after the influence of non-verbal IQ had been accounted for. These authors suggest that motor skills should have a pivotal role in educational interventions designed to support the development of early mathematical skills, which would be highly beneficial because children with ADHD symptoms are at higher risk for reading/spelling and math difficulties compared to children without ADHD symptoms (see also Czamara et al., 2013).

Handwriting skill improvement may not necessarily lead to better academic outcomes; however, it would help in making texts easier to read. This would be helpful for children with ADHD because more positive evaluations of nicely handwritten essays are associated with processing legible material (Greifeneder et al., 2010). That is, teachers are more likely to give higher grades to work that they find 'easy' to read.

The intervention should also include written expression abilities because ADHD students would exhibit greater deficits in written expression tasks requiring organization and attention to detail, especially in the context of a complex task (Molitor, Langberg, & Evans, 2016).

Given that, as mentioned previously, poor handwriting may negatively affect academic outcomes, and ADHD symptoms, primarily inattention, relates to poor motor fine coordination, fine motor training should be included as part of the ADHD comprehensive treatment.

4.2. Limits and future research

Further studies should explore how poor motor fine performance is a feature of ADHD and if it is possible to enhance this performance with training. They should also explore how enhancing fine motor abilities affects the academic outcomes of ADHD children. It would also be interesting to determine in what way this fine motor effect is maintained when comorbid disorders (e.g., Developmental Coordination Disorder, Specific Learning Disabilities, etc.) are excluded. In addition, the potential impact of some covariates (e.g., the intelligence, pharmacological status) in the fine motor coordination of ADHD individuals has not been explored here, and should be considered in follow-up studies.

5. Conclusion

In summary, this study provides empirical evidence for the hypothesis that children with ADHD have a poorer fine motor performance than children with typical development. The performance of the ADHD children is characterized by a less accurate line drawing, meaning more mistakes, which is related to the inattention dimension but not to the hyperactivity or impulsivity dimensions. This result suggests that fine motor difficulties would affect both clinical subtypes of ADHD (predominantly inattentive and combined presentations). Given the relationship between handwriting performance and long-term academic outcomes, we recommend including training and enhancement of the fine motor skills for more comprehensive ADHD interventions.

Conflict of interest statement

The authors report no biomedical financial interests or potential conflicts of interest.

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