Revista de Psicodidáctica, 2014, 19(1), 125-143
www.ehu.es/revista-psicodidactica
ISSN: 1136-1034 eISSN: 2254-4372

DOI: 10.1387/RevPsicodidact.7510

Math Competence and Executive Control Skills in Students with Attention Deficit/Hyperactivity Disorder and Mathematics Learning Disabilities

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Abstract

Attention deficit disorder with hyperactivity (ADHD) shows a high comorbidity with mathematics learning disabilities (MLD).The aim of this study was to analyze the math skills and central executive skills (attention) of 288 students diagnosed with ADHD + MLD, ADHD, MLD or without disabilities or ADHD (comparison group). A descriptive ex post facto design was used, and two assessment instruments, TEMA 3 and TOVA, were employed. The results showed significant differences in attentional variables between the two groups with ADHD and the two without this disorder, resulting in two homogeneous subgroups, one made up of the ADHD and ADHD + MLD groups, and the other of the MLD and COM groups. However, in mathematical competence, ADHD and MLD influence in formal and informal competence in different ways. We conclude that ADHD + MLD comorbidity does not condition attentional capacity, but it does condition mathematical competence.

Keywords: ADHD, MLD, mathematical competence, central executive.

Resumen

El trastorno por déficit de atención con hiperactividad (TDAH) presenta una elevada comorbilidad con las dificultades de aprendizaje de las matemáticas (DAM). El objetivo de este estudio era analizar qué competencias matemáticas y qué habilidades del ejecutivo central (atención) presentaban 288 estudiantes, clasificados con TDAH + DAM, con TDAH, con DAM y sin dificultades ni TDAH como grupo comparativo. Se planteó un diseño descriptivo *ex post facto*, con dos instrumentos de evaluación, el TEMA 3 y el TOVA. Los resultados mostraron diferencias significativas en las variables atencionales entre los dos grupos con TDAH y los dos sin este trastorno, presentando dos subconjuntos homogéneos, uno formado por TDAH y TDAH + DAM, y otro por DAM y COM, sin embargo en la competencia matemática, el TDAH y las DAM influyen de forma diferente entre competencias formales e informales. Se concluye que la comorbilidad TDAH + DAM no condiciona la capacidad atencional, pero sí la competencia matemática.

Palabras clave: TDAH, DAM, competencia matemática, ejecutivo central.

Acknowledgements: Grants awarded to the authors (Principal Luis Alvarez) from I+D+i grants Princedom of Asturias (Ref.: SV-PA-13-ECOEMP-55) supported this work.

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Introduction

The comorbidity of Attention Deficit with Hyperactivity Disorder (ADHD) with Learning Difficulties (LD) generally ranges between about 25-35% (Mayes, Calhoun, & Crowell, 2000). If such learning difficulties occur specifically in the area of Mathematics (MLD), their degree of association with ADHD will vary between 18% (Capano, Minden, Chen, Schachar, & Ickowicz, 2008) and 31% (Zentall, 2007). According to Kauffman and Nuerk (2008), this comorbidity manifests in the fact that students with ADHD present significantly poorer development in basic number processing skills such as comparing the magnitude of one-digit numbers, counting, or writing dictated numbers. Thirty per cent of these students will not reach a basic level of math competence that is compatible with their intellectual level because whereas low performance in this area seems to decrease with age in the general population, in students with ADHD, the discrepancy between math competence and intellectual capacity tends to increase (Jordan, Hanich, & Kaplan, 2003).

The attempts of current research to explain the relation between ADHD and LD are based on the model of Rapport, Scanlan and Denney (1999). This model relates academic problems to two elements, the first more closely related to cognitive aspects, such as vigilance, attention, or working memory (WM), while the second is related to early development of behavior problems. Thus, ADHD and problematic behavior interfere indirectly with school performance due to their negative and direct influence on classroom behavior and cognitive skills, both of which are directly related to performance.

In this study, we attempt to underline some aspects of the former element, related to cognitive aspects of ADHD and MLD, on the basis that a deficit in the central executive compromises the skills required to develop learning (Miranda, Colomer, Fernández, & Presentación, 2012). Many of the activities that take place when learning mathematics will be problematic for children with WM deficits because such activities demand certain skills to simultaneously process and store information, and the central executive is in charge these processes (Andersson & Lyxel, 2007). Thus, in the model proposed by Baddeley (1998), the central executive is in charge of coordinating, monitoring, and sequencing the functioning of the two systems, the visuo-spatial component and the phonological loop, in addition to long-term attentional control and coordination of multiple tasks. In this regard, given the heterogeneous nature of the central executive, the assessment of its functioning in students with MLD who also have ADHD focuses on the assessment of errors in recall tasks, inhibitory processes of irrelevant information, or on indicators of sustained attention (Monette, Bigras, & Guay, 2011; Passolunghi & Cornoldi, 2008).

According to Marzocchi, Cornoldi, Lucangeli, De Meo and Fini (2002), students with ADHD have problems concentrating on relevant, subtle, or masked stimuli, suggesting that errors in problem-solving tasks could be due to their inattention to meaningful stimuli. Moreover, according to these authors, the irrelevant information could occupy an important space in the WM of students with attention deficit, limiting their capacity for adequate decisions when solving math problems. Along these same lines, Preston, Heaton, McCann, Watson, and Selke (2009) reported that at least some of the academic difficulties experienced by children with ADHD are due to their scarce capacity to inhibit stimuli and to shift their attention, and not to the presence of specific learning difficulties. Miranda, Meliá and Taverner (2009) indicate that WM deficit is characteristic of the presence of MLD, whereas attentional and inhibitory control deficits correspond to ADHD. For these authors, students with both problems would have a combination of the limitations present in each one and, in addition, they would experience more severe impairment of inhibitory control than students with ADHD.

Altogether, many studies have attempted to identify the relations between MLD and ADHD (Barkley, 1997; Blake-Greenberg, 2003; Kercood, Zentall, & Lee, 2004; Sergeant, Van der Meere, & Oosterlaan, 1999; Zentall, 2007). Some of them analyze in more depth the differences between math performance and the different subtypes of the disorder, obtaining contradictory results (Lucangeli & Cabrele, 2006; Merrell, 2005; Merrell & Tymms, 2001).

Goals

In accordance with the results of prior research, we wish to determine firstly, which aspects of cognitive processing in the central executive characterize students with a combined diagnosis (ADHD and MLD) versus students with an individual diagnosis (ADHD or MLD), and the nature of such processing in comparison with a group of students without ADHD or MLD. For this purpose, we will analyze omissions as a measure of attention, commissions as a measure of impulsivity, response time as a measure of processing, variability as a measure of response inconsistency, and D’ as quality of attention. All these variables will be analyzed through a Continuous Performance Test (CPT) such as the *Test of Variables of Attention*

(TOVA; Greenberg, 1996). We anticipate that students with a diagnosis of ADHD, independently of the presence of an MLD diagnosis, will be characterized by less inhibitory control, displaying a poorer performance when the attentional resources of the task are demanding, and their response pattern will also be significantly more variable, with no regularity or apparent balance.

The second goal will be to compare the mathematic competences of students with ADHD+MLD, students with ADHD, students with MLD, and a comparative group of students without MLD or ADHD. According to the *Test of Early Mathematics Ability* (TEMA 3; Ginsburg & Baroody, 2003) of the assessment of mathematics abilities, these competences can be classified as informal and formal mathematics. Informal mathematics refer to the notions and procedures acquired outside of the school setting, whereas formal mathematics refer to the abilities and concepts children learn in school. As generalization and automation of math abilities are required for both categories (formal and informal), students with MLD are expected to be more affected. However, with regard to ADHD students' performance in this type of tasks, the lack of empirical evidence makes it difficult to anticipate the results.

Method

Participants

In the present study, 288 students from the first cycle of Primary Education were participants. Their age ranged from 6 to 9 years, and they were distributed as a function of sex and grade, as shown in Table 1. In accordance with the design, this sample was made up of 4 groups, 72 diagnosed with ADHD (ADHD Group), 62 diagnosed with MLD (MLD Group), 82 diagnosed with ADHD and MLD (ADHD+MLD Group), and a comparison group of 72 students without ADHD or MLD (COM Group). None of the participants in this study had an IQ lower than 80 or higher than 130 (M = 91.41, SD = 5.55). Their IQ scores were normally distributed with higher IQ in the groups without ADHD, $F(3, 284) = 7.857$, $p = .000$, $\eta 2 = .077$, as measured with the Wechsler Intelligence Scale for Children-IV (Wechsler, 2005). No significant group differences were found as a function of age, $F(3, 284) = .066$, $p = .978$, $\eta 2 = .001$, but there were differences as a function of sex, $\chi^2 = 18.00$, $p = .000$.

Table 1

Number of Participants by Group and Sex, Means and Standard Deviations of Age, IQ and the EDAH Scale

	Groups				Total sex
	ADHD + MLD	ADHD	MLD	COM	
Male (*N*)	39	56	45	40	180
Female (*N*)	23	16	37	32	108
Total group (*N*)	62	72	82	72	288
Age *M* (*SD*)	7.01 (.68)	7.05 (.72)	7.03 (.68)	7.01 (.65)	
IQ *M* (*SD*)	89.95 (6.16)	90.77 (5.39)	93.07 (4.80)	90.09 (5.97)	
EDAH *M* (SD)	94.79 (2.30)	95.05 (1.99)	59.29 (8.72)	59.69 (7.47)	

Note. ADHD: Attention Deficit with Hyperactivity Disorder; MLD: Mathematical Learning Difficulties; COM: comparison group; IQ: intelligence quotient; EDAH: "Cuestionario de Evaluación del Déficit de Atención con Hiperactividad" [Assessment of Attention Deficit and Hyperactivity Questionnaire].

Sample Selection

Diagnosis of ADHD was carried out by the neuropediatrician according to the criteria of the *Diagnostic and Statistical Manual of Mental Disorders-IV-TR* (American Psychiatric Association, 2000). For this purpose, the adaptation of semi-structured interview of ADHD for parents was applied *Diagnostic Interview Schedule for Children DISC-IV* (Shaffer, Fisher, Lucas, Dulcan, & Schwab-Stone, 2000). To ensure the correct assignation of the students to the corresponding groups, the teachers completed the *"Cuestionario de Evaluación del Déficit de Atención con Hiperactividad"* (EDAH*;* (Farré & Narbona, 1998). Statistically significant group differences in the ADHD scores of the EDAH were confirmed, $F(3, 284) = 794.008$, $p = .000$, $\eta 2 = .893$. The group means are presented in Table 1.

MLD students were selected when a significant discrepancy between intellectual capacities and math performance was detected in the absence of an intellectual deficit in the basic cognitive processes that could justify the disparity. This was diagnosed by specialists from the psychopedagogical team after ruling out the possibility that the learning problems were due to other difficulties (visual, auditive, motor, emotional, etc.). When the regular teacher detected a student with low performance and no apparent justification (motivation problems, discipline, etc.), the psychopedagogical team analyzed the real magnitude of the learning delay to determine whether the math performance was significantly lower than the intellectual capacity of that student. The discrepancy was considered significant when performance was two or more years below the general intellectual capacity. Secondly, in the absence of some general intellectual deficit and in the presence of a significant discrepancy between intellectual capacities and performance, a deficit in the basic cognitive processes that would justify the discrepancy was sought. Thirdly, the possibility that the learning problems were due to difficulties other than MLD (visual, auditive, motor, emotional, etc.) was ruled out. Lastly, after the first three steps were completed and taking into account the characteristics (deficiencies and skills) of the students with MLD, modifications were made in the access conditions to the study plan, which seem to be preventing students from following the ordinary syllabus.

The participants were assigned to one of the three experimental groups (ADHD, MLD, ADHD+MLD) or to the comparison group, according to the neuropediatric (DSM-IV; APA, 2000) and the psychoeducational (EDAH) diagnoses, and taking comorbidity into account when both diagnoses were made (ADHD+MLD).

Design

We used a 2 × 2 descriptive ex post facto design to compare the groups as a function of the presence or absence of ADHD; the second factor was the presence or absence of MLD, thereby forming 4 groups (ADHD, MLD, ADHD+MLD, and COM), which allowed us to detect differences among the clinical groups with regard to the comparison group, and to isolate the causes of the differences. We included the variables age, IQ, and sex as covariates.

Procedure

To perform the investigation, we requested parents' informed consent for their children to participate in the study, ensuring them that the study complied with the established deontological code and of the anonymity and confidentiality of the data obtained.

After applying the tests to select and assign the students to the groups, individual assessment was performed by an educational psychologist. This assessment included the *TEMA 3* (Ginsburg & Baroody, 2003) mathematical ability test, as well as the assessment of attention and the executive control by means of the *TOVA* test (Greenberg, 1996). We also assessed intelligence with the

Wechsler Intelligence Scale for Children-IV (WISC-IV; Wechsler, 2005). The administration order of the tests was randomized for all the students but, due to the fact that assessment of these groups was performed during the school course, it was impossible to establish a fixed number of sessions, as this depended on the dynamics of each center and on each child's academic rhythm. Test application was counterbalanced and the order was selected with reference to the application time because the diverse tasks did not influence each other.

Instruments

Below are described the instruments used to confirm sample selection as a function of the factors considered in the design (ADHD and MLD).

Diagnostic Interview Schedule for Children IV (DISC-IV; Shaffer et al., 2000): This highly structured diagnostic interview for children allows performing the diagnosis according to the DSM-IV (APA, 2000) criteria for ADHD. This interview is currently one of the most extensively employed in international research and child and youth psychiatric epidemiology, as it is well validated, both in its original version (Lewczyk, Garland, Hurlburts, Gearity, & Hough, 2003) and in Spanish (Canino et al., 2004).

Escala de Evaluación del Déficit de Atención con Hiperactividad (EDAH [in English, Scale of Assessment of Attention Deficit with Hyperactivity]; Farré & Narbona, 1997): This scale for teachers has 20 items that provide information about the presence or absence of ADHD and allows distinguishing between predominantly hyperactive-impulsive ADHD and inattentive ADHD .

The instruments used in the individual assessment were the *TOVA* (Greenberg, 1996) to measure the variables related to executive control and attentional capacity; the *Test of Early Mathematics Abilities 3* (TEMA 3; Ginsburg & Baroody, 2003) to appraise formal and informal math competence, and the *WISC-IV* (Wechsler, 2005).

The *Wechsler Intelligence Scale for Children-IV* (WISC-IV; Wechsler, 2005) is an individually applied instrument to assess the intelligence of children or adolescents between ages 6 and 16 years-11 months. It is made up of 15 subtests that provide information about the intellectual functioning in specific cognitive areas, with a score of Total Intelligence Quotient (TIQ).

The *Test of Variables of Attention* (TOVA; Greenberg, 1996): is a Continuous Performance Test (CPT), consists of the presentation on a computer screen of two stimuli: at the onset of the first one—a square at the upper edge of the screen—, the subject must press a button; at the onset of the second stimulus —a square at the lower edge—, the subject should not do anything. The TOVA controls omissions (the subject does not detect a correct stimulus), commissions (the subject does not respond to a correct stimulus), response time (milliseconds in which the subject emits the response), and variability (difference between response times), D' (quality of performance throughout the test), and the General Executive Control Index (GECI), which is the result of the sum of the response time of the first half, D' of the second half, and the total variability (a GECI lower than –1.80 indicates deficit in the executive control; González-Castro et al., 2010).

TEMA 3 (Ginsburg & Baroody, 2003): This test assesses mathematics ability, classifying mathematics as informal and formal. Informal mathematics are assessed with four subtests: Counting, Quantity Comparison, Informal Calculation, and informal Concepts. Counting consists of the identification and flexible use of sequences (a basic skill needed to represent—or internalize—quantity, which also facilitates access to mental calculation). Quantity Comparison involves number sense, the knowledge of number sequence, which is linked to the recognition of the direction in which numbers increase or decrease. Informal Calculation refers to using numbers to solve simple situations that involve adding and subtracting. Lastly, the Informal Concept assesses the number concept from the embodied approach as an aggregate of elements, differentiating that the part is less than the whole (it includes the conservation of material).

The formal mathematics are assessed through Conventionalisms, Number Facts, Formal Calculation, and Formal Concepts. Conventionalisms refer to the capacity to read and write quantities; that is, a coding and decoding task. Number Facts involve knowledge about the result of simple operations of addition, subtraction, and multiplication without needing to perform the calculation at that time. Formal Calculation involves performing additions and subtractions of increasing difficulty. Lastly, the Formal Concepts assesses the number concept from the symbolic and iconic viewpoint.

None of the tasks require much reading ability; hence, reading difficulties do not affect the result of math competence.

Results

As a function of the partial goals, we present the results of the TOVA and TEMA 3 separately.

Results of the TOVA

Table 2 shows the means and standard deviations corresponding to the six indicators of executive

Table 2

Means, Standard Deviations and Between-subject Tests for the TOVA Variables

	Groups				F (p)	η_p^2
	ADHD $N = 72$	MLD $N = 82$	ADHD + MLD $N = 62$	COM $N = 62$		
	M (SD)					
Omissions	71.38 (5.63)	94.42 (4.83)	73.25 (4.63)	94.37 (4.93)	456.689 (< .001)	(.830 b)
Commissions	80.15 (6.08)	97.07 (5.75)	82.04 (3.62)	96.54 (5.76)	195.314 (< .001)	(.676 b)
Variability	71.38 (6.42)	94.95 (5.70)	73.46 (5.53)	95.22 (5.87)	321.679 (< .001)	(.774 b)
Response Time	74.36 (5.74)	95.48 (5.76)	76.70 (4.52)	95.66 (5.58)	312.825 (< .001)	(.770 b)
D'	–1.81 (.75)	1.25 (.60)	–1.73 (.66)	1.25 (.59)	480.825 (< .001)	(.837 b)
GECI	–3.48 (.88)	2.75 (.94)	–3.60 (.88)	2.62 (.83)	1146.280 (< .001)	(.924 b)

Note. ADHD: Attention Deficit with Hyperactivity Disorder; MLD: Mathematical Learning Difficulties; COM: Comparison group; partial eta-squared coefficient (η_p^2) were calculated to measure the effect size: b) η_p^2 =.14 (large effect).

control provided by the TOVA (omissions, commissions, response time, variability, D', and GECI). To correctly interpret the information of the TOVA, it should be taken into account that low results indicate more deficits and vice versa.

The multivariate contrasts of covariance (MANCOVA) show an effect of the variable Group in the *TOVA* variables taken as a whole, $\lambda = .063$, $F(3, 281) = 72.078$, $p = .000$, $\eta p^2 = .603$. Regarding the covariates, neither IQ ($p = .685$) nor sex ($p = .194$) showed statistically significant effects, but age did, $\lambda = .895$, $F(6, 276) = 5.442$, $p = .000$, $\eta p^2 = .105$.

The tests of between-subject effects yielded statistically significant differences for six of the TOVA variables. The effect size, calculated through partial eta-squared, indicates a large effect in all these variables, with values ranging from .676 for the variable commissions to .924 for the variable GECI, as shown in Table 2.

The multiple comparison post hoc Scheffé contrasts revealed statistically significant differences of means between the groups with ADHD and those that did not present this disorder. That is, as a function of all the TOVA measures, the sample could be grouped into two homogeneous subgroups, one made up of the ADHD and the ADHD+MLD groups and the other comprised of the MLD and the COM groups, as shown in Table 3.

Table 3

Post-hoc Results and Differences of Means (I-J) of the TOVA Variables

	Group Comparisons					
	ADHD vs. MLD	ADHD vs. ADHD + MLD	ADHD vs. COM	MLD vs. ADHD + MLD	MLD vs. COM	ADHD + MLD vs. COM
	Differences of means (I–J)					
Omissions	–23.03 (***)	–1.86 (n.s.)	–22.98 (***)	21.16 (***)	.05 (n.s.)	–21.11 (***)
Commissions	–16.92 (***)	–1.89 (n.s.)	–16.38 (***)	15.02 (***)	.53 (n.s.)	–14.93 (***)
Variability	–23.56 (***)	–2.07 (n.s.)	–23.83 (***)	21.48 (***)	–.27 (n.s.)	–21.75 (***)
Response Time	–21.12 (***)	–2.34 (n.s.)	–21.30 (***)	18.77 (***)	–.17 (n.s.)	–18.95 (***)
D’	–3.07 (***)	–.08 (n.s.)	–3.07 (***)	2.99 (***)	–.003 (n.s.)	–2.99 (***)
GECI	–6.23 (***)	.11 (n.s.)	–6.10 (***)	6.35 (***)	.13 (n.s.)	–6.22 (***)

Note. ADHD: Attention Deficit with Hyperactivity Disorder; MLD: Mathematical Learning Difficulties; COM: Comparison group; I-J: Differences of means (*I* = mean first group; *J* = mean second group); *n.s.*: non significant.

*** $p < .001$.

Results of the assessment of TEMA 3 Mathematical Ability Test

Table 4 shows the means and standard deviations of the eight indicators of the TEMA 3 (Ginsburg & Baroody, 2003).

The MANCOVAS show an effect of the variable typology or diagnosis on the informal mathematics taken as a whole, $\lambda = .445$, $F(3, 281) = 21.943$, $p = .000$, $\eta p^2 = .236$. With regard to the covariates, a statistically significant effect was found in the variable IQ, $\lambda = .957$, $F(4, 278) = 3.154$, $p = .015$, $\eta p^2 = .043$, as well as in the variable age, $\lambda = .443$, $F(4, 278) = 87.300$, $p = .000$,

Table 4

Means, Standard Deviations and Tests of Between-subject Effects of the TEMA 3 Variables

		Groups				
		ADHD $N = 72$	MLD $N = 82$	ADHD+MLD $N = 62$	COM $N = 62$	F (p) (η_p^2)
		M (*SD*)				
Informal mathematics	Counting	16.77 (3.29)	14.69 (9.06)	14.59 (3.04)	16.51 (3.38)	3.747 (<.05) (.038 a)
	Quantity Comparison	4.18 (.75)	3.15 (.76)	3.27 .90)	4.18 (.77)	73.039(<.001) (.438 b)
	Informal Calculation	4.19 (.72)	3.10 (.70)	3.59 (.71)	4.37 (.70)	66.397 (<.001) (.415 b)
	Informal Concepts	2.33 (.50)	2.19 (.63)	2.08 (.83)	2.58 (.68)	7.040 (.154) (.070 a)
Formal mathematics	Conventionalisms	5.31 (1.14)	3.75 (.93)	4.03 (1.10)	5.48 (.96)	129.380 (<.001) (.580 b)
	Number Facts	2.15 (2.28)	1.29 (1.59)	1.41 (1.59)	2.12 (2.21)	14.054 (<.001) (.130 b)
	Formal Calculation	1.34 (1.30)	1.23 (1.37)	1.21 (1.30)	1.50 (1,34)	2.806 (.040) (.029 a)
	Formal Concepts	1.48 (.85)	1.18 (.65)	.87 (.68)	1.65 (.90)	18.786 (<.001) (.167 b)

Note. ADHD: Attention Deficit with Hyperactivity Disorder; MLD: Mathematical Learning Difficulties; COM: Comparison group; partial eta-squared coefficient (η_p^2) were calculated to measure the effect size: a) $\eta_p^2 = .06$ (medium effect), b) $\eta_p^2 = .14$ (large effect).

$\eta p^2 = .557$, but no statistically significant differences were found as a function of sex ($p = .081$).

However, there was an effect of the variable typology or diagnosis on the formal mathematics variables taken as a whole, $\lambda = .382$, $F(3, 281) = 26.907$, $p = .000$, $\eta p^2 = .274$. Regarding the covariates, there was an statistically significant effect in the variable age, $\lambda = .202$, $F(4, 278) = 275.107$, $p = .000$, $\eta p^2 = .798$, but no differences were found as a function of sex ($p = .201$), or of IQ ($p = .085$).

Table 5

Post-hoc Results and Differences of Means (I-J) of the TEMA 3 Variables

		Group Comparisons					
		ADHD vs. MLD	ADHD vs. ADHD + MLD	ADHD vs. COM	MLD vs. ADHD + MLD	MLD vs. COM	ADHD + MLD vs. COM
		Differences of means (I–J)					
Informal mathematics	Counting	2.08 (n.s.)	2.18 (n.s.)	.26 (n.s.)	.09 (n.s.)	–1.81 (n.s.)	–1.91 (n.s.)
	Quantity comparison.	1.02 (***)	.90 (***)	.00 (n.s.)	–.11 (n.s.)	–1.03 (***)	–.89 (***)
	Informal calculation	1.08 (***)	.59 (***)	–.18 (n.s.)	–.48 (n.s.)	–1.26 (***)	–.77 (***)
	Informal concepts	.13 (n.s.)	.25 (n.s.)	–.25 (n.s.)	.11 (n.s.)	–.38 (**)	–.50 (***)
Formal mathematics	Conventio-nalisms	1.56 (***)	1.28 (***)	–.16 (n.s.)	–.27 (n.s.)	–1.73 (***)	–1.45 (***)
	Number facts	.86 (*)	.73 (n.s.)	.02 (n.s.)	–.12 (n.s.)	–.83 (*)	–.70 (n.s.)
	Formal calculation	.11 (n.s.)	.13 (n.s.)	–.15 (n.s.)	.02 (n.s.)	–.26 (n.s.)	–.29 (n.s.)
	Formal concepts	.30 (n.s.)	.61 (***)	–.16 (n.s.)	.31 (n.s.)	–.46 (**)	–.78 (***)

Note. ADHD: Attention Deficit with Hyperactivity Disorder; MLD: Mathematical Learning Difficulties; COM: Comparison group; I-J: Differences of means (*I*=mean first group; *J*=mean second group); *n.s.*: non significant.

** $p < .005$. ***$p < .001$.

The multiple post-hoc Scheffé comparisons revealed statistically significant differences of means and in math ability as a function of the aspects assessed, as seen in Table 5. With regard to the informal mathematics aspects, the variable Counting did not differentiate any of the groups; similar results were found for the variables Quantity Comparison and Informal Calculation, with differences as a function of the diagnosis of MLD; that is, students with MLD, both independently or comorbidly with ADHD, achieved very low results. The variable Concepts presented differences exclusively between the COM group, which obtained better results, and the two MLD groups (MLD and ADHD + MLD).

In contrast, in the formal mathematics variables, there were clear statistically significant differences in the variable Knowledge of Conventionalisms, as with the previous variables Quantity Comparison and Informal Calculation. Formal Calculation variable revealed no differences among the four groups, and Number Facts only yielded small differences between the ADHD and MLD groups and between the MLD and COM groups, with better results for the groups without MLD. Lastly, the variable Basic Concepts presented differences between the ADHD and ADHD + MLD groups, but the most interesting aspect is that the MLD group obtained worse results than those of the COM group, and these differences increased when comparing the ADHD + MLD group with the COM group.

Discussion

In this study, we attempted to analyze the differences in some central executive skills and in basic math competences of participants with ADHD+MLD, ADHD, MLD, and participants without ADHD or MLD. With regard to the central executive, it is concluded that there are some differences in the functioning of students with ADHD, which is worse than in students without ADHD, as specified in prior studies (Lahey & Willcutt, 2010; Soroa, Iraola, Balluerka, & Soroa, 2009). However, these results occur independently of whether or not ADHD is associated with other disorders, and performance does not worsen when MLD is comorbid with ADHD. Specifically, the difficulties undergone by students with ADHD+MLD can be due to their scarce capacity to inhibit and shift their attention, and not to the presence of specific learning difficulties (Monette et al., 2011; Preston et al., 2009).

Referring to math competences, it is noted that the performance of ADHD group was similar to that of the COM group in informal skills (e.g., Quantity Comparison and Informal Calculation) whereas, when comparing the COM group or the ADHD group with the two MLD groups, the performance of the MLD groups was worse, independently of the association of MLD with ADHD. This may indicate that typical ADHD behaviors do not affect the acquisition of these skills, and therefore, they are considered specific to subjects with MLD, and their identification is essential for an accurate diagnosis. Moreover, when forming Informal Concepts (where there are only differences between MLD and the COM group), the comorbidity of ADHD + MLD, impairs the acquisition of this ability, which depends on mental representation. In short, Informal mathematics and the conservation skills underlie, is acquired without the mediation of formal learning (Miranda et al., 2012). These results reveal the need for a methodology for early learning of mathematics in people with ADHD, which would be more effective if it was visual and manipulative. In the case of the MLD group, comorbidity with ADHD worsens their performance in the skills Quantity Comparison and Informal Calculation. According to Kauffman and Nuerk (2008), this may be due to the effect of ADHD in the skills of Number Processing (comparing numbers, counting, writing dictated numbers, etc.) which, as noted by Preston et al. (2009), could be related to a deficit in WM and the executive functions (Miranda et al., 2012) and not to specific MLDs.

If, in contrast, we focus on the formal competences, the pattern of results changes with regard to the informal ones. We no longer observe such differentiated groups of ADHD and MLD, except for the case of the variable Knowledge of Conventionalisms, which follows the same tendency as Quantity Comparison and Informal Calculation. In this case, MLD students have more difficulties to associate the symbol with the reference concept and reach a simple result without performing a mathematical calculation. The results therefore reflect two clearly differentiated blocks, groups with and without MLD. In the case of the variable Informal Calculation, we underline the lack of significant differences between any of the groups, which could be due to the fact that this skill is procedural (algorithms learnt by means of formal learning, becoming automatic without the need of a specific skill). Summing up, in the formal competences, when comparing the ADHD group with the ADHD + MLD group, they do not differ in Number Facts or in Formal Calculation, indicating that these two variables do not specifically differentiate people with MLD. However, some differences in the variables Knowledge of Conventionalisms and Formal Concepts allow the detection of MLD.

It is important to underline that forming Formal and Informal Concepts is very closely related to the assimilation of new information and its integration with prior knowledge. These processes of assimilation and integration are essential in the acquisition of conceptual knowledge, a procedure that requires more meaningful learning than the so-called mechanical mastery of formal calculation, because this learning is more flexible and less automated (Vicente, Orrantia, & Verschaffel, 2008).

But why is the execution by ADHD and MLD students in some of these informal and formal skills (e.g., calculation) similar? The data provided show that the main deficit is not caused by specific difficulties in the area of mathematics but in the automation and recall of information and it is clearly associated with variables related to the WM (Passolunghi & Cornoldi, 2008). Whereas ADHD students have no problems with the basic skill Informal Calculation, and their performance is significantly different from that of the MLD and ADHD+MLD groups, in Formal Calculation, their performance is similar to that of these groups. Although both groups, MLD and ADHD, present common difficulties, the reasons for them may be different (although the end result is the same, the process is different). Participants with MLD have difficulties in the basic or previous skills, whereas participants with ADHD have difficulties because they are in capable of planning, organizing, inhibiting, and maintaining their attention on the task, that is, in skills more closely related to the central executive (Willcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005).

Lastly, future research should solve the limitations of the present study, analyzing the variables that condition executive functioning and that are more closely related to math competence. Moreover, research should study in more depth other variables related to math competence that cause more difficulties in groups with ADHD and MLD in order to carry out interventions better adapted to each one of these profiles (Cueli, García, & González-Castro, 2013) and at earlier ages. It should also be taken into account that, as observed herein, ADHD students achieve better results when they learn in settings that underline manipulative and iconic aspects, through guided discovery. To reach this goal, some studies advise the use of new technologies, specifically, those that provide interactive learning environments, promoting the development of cognitive and metacognitive processes, which, according to Walker et al. (2012), produce positive effects not only in mathematical knowledge, but also in attitudes.

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Received date: 17-03-2013 Review date: 04-06-2013 Accepted date: 18-09-2013