Psychiatry Research 278 (2019) 289–293

Contents lists available at ScienceDirect

Psychiatry Research

journal homepage: www.elsevier.com/locate/psychres

Sex differences in neuropsychological functioning among children with attention-deficit/hyperactivity disorder

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ARTICLE INFO

Keywords:
Attention-deficit/hyperactivity disorder
ADHD
Neuropsychological functioning
Cognition
Children
Sex

ABSTRACT

Cognitive impairments are often reported in research on children with attention-deficit/hyperactivity disorder (ADHD). However, studies analyzing sex differences in this context are still sparse. This study aimed to compare the neuropsychological performance of boys and girls with ADHD across several cognitive domains. Verbal comprehension, perceptual reasoning, working memory, processing speed, and general cognitive performance were assessed in 240 children aged 6–17 years: 120 children (65 boys) with a clinical diagnosis of ADHD and 120 typically developing children (60 boys). Underperformance of children with ADHD compared to controls was observed in all the evaluated cognitive domains, except for verbal comprehension. Significantly lower scores in perceptual reasoning, with a medium effect size, were found in girls with ADHD relative to boys, although the sexes did not significantly differ in terms of the remaining variables. Children's ADHD subtypes did not correlate significantly with any performance measure, and no significant interaction effects between children's age and sex were noted in the results. The performance commonalities found between boys and girls with ADHD outweighed the differences, which highlights the importance of further research on cognitive dysfunction in girls with ADHD, regardless of sex differences in the prevalence of the disorder.

1. Introduction

Attention-deficit/hyperactivity disorder (ADHD) is one of the most frequently occurring neurodevelopmental disorders in child psychopathology, with a reported worldwide prevalence of around 3.4 (Polanczyk et al., 2015). This disorder manifests in a persistent pattern of inattention and/or hyperactivity/impulsivity that interferes with daytime functioning, characterized by deficient development in the personal, family, social or school settings (American Psychiatric Association, 2013). Moreover, ADHD is associated with a series of comorbid conditions, such as conduct disorders, oppositional defiant disorder, autism spectrum disorders, and specific learning disorders (Biederman et al., 2008; Mayes et al., 2000; Melegari et al., 2018; Setyawan et al., 2018; Zablotsky et al., 2017). The intensity and significance of these factors have pushed this disorder to the forefront of many current investigations.

The school environment is particularly affected by ADHD due to the weaker academic performance shown by children with this disorder, relative to their peers (Daley and Birchwood, 2010; Fabiano and Pyle, 2019; Loe and Feldman, 2007), placing them at higher risk of failure or school dropout (Barbaresi et al., 2007; Barkley et al., 2008). The symptoms of the disorder, as well as the cognitive- and executive-level deficits associated with the disorder, contribute to this poorer academic performance (Daley and Birchwood, 2010; Merrell et al., 2017; Sonuga-Barke, 2002).

In particular, numerous studies have identified associations between ADHD and neuropsychological impairments in children across domains or areas such as sustained attention, working memory, response inhibition, and processing speed, among others (e.g., Fenollar-Cortés et al., 2015; Jiménez-Figueroa et al., 2017; Li et al., 2017; Lin et al., 2017; Maehler and Schuchardt, 2016; Rodríguez et al., 2014; Stern and Shalev, 2013; Villemonteix et al., 2017). However, the aforementioned findings are not entirely consistent across studies, and it is crucial to conduct more research, which, by exploring the involvement of other variables, may help to account for the heterogeneous results of previous studies. For instance, it may be relevant to consider the possible

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https://doi.org/10.1016/j.psychres.2019.06.028
Received 26 January 2019; Received in revised form 19 June 2019; Accepted 19 June 2019
Available online 24 June 2019
0165-1781/

influence of sex on the poorer neuropsychological performance observed in children with ADHD.

Despite the large amount of available evidence on neuropsychological deficits linked to ADHD, few studies have analyzed the differences between boys and girls in this respect, and their results are far from consistent. Although the results of some relevant meta-analyses clearly point to greater intellectual deficits in girls with ADHD, relative to boys with ADHD (Gaub and Carlson, 1997; Gershon, 2002), other results suggest similar profiles of neuropsychological functioning in girls and boys with ADHD. For instance, in the study conducted by Seidman et al. (2005), differences between boys and girls were limited to only two of the 17 variables assessed (i.e., set shifting and categorization). Also, Yang et al. (2004) found differences between both sexes in only one (i.e., block design scores) out of a total of 16 main variables.

Moreover, discrepancies are also observed across studies of the specific deficits reported in relation to boys and girls with ADHD. Newcorn et al. (2001) reported higher impulsivity errors in boys with ADHD than in girls with ADHD in a computer performance test (CPT), whereas no such disparities were noted in any of the CPT performance scores tested by Yang et al. (2004). The results of the studies conducted by Seidman et al. (2005) and Wodka et al. (2008) also revealed similar deficits in planning and response inhibition in boys and girls with ADHD, contrary to the findings O'Brien et al. (2010) reported: greater deficits in planning among girls and greater deficits in response inhibition among boys.

Further comparison of cognitive performance between boys and girls with ADHD may help to enhance the knowledge already assembled about the difficulties faced by each sex. In turn, this may enable a more appropriate adaptation of the strategies targeted at decreasing their deficits, and thereby reduce the rates of failure and school dropout among both girls and boys. Although the disorder is estimated to be up to nine times more prevalent among boys than girls in clinical samples (see review by Skounti et al., 2007), this seems to be due more to the lower amount of externalization of problems that girls show (Gershon, 2002), or parental perception of ADHD symptoms (Mowlem et al., 2019) than to the incidence of ADHD. Regardless of the actual prevalence among boys, relative to girls, findings of previous studies suggest similar school performance among boys and girls with ADHD and the same level of difficulty faced at school by both sexes (see review in Rucklidge, 2010).

In light of the above points, the goal of this study was to evaluate the differences in neuropsychological functioning between boys and girls with ADHD, in terms of their performance in the following cognitive domains: verbal comprehension, perceptual reasoning, working memory, processing speed, and overall cognitive or intellectual ability. To distinguish the sex differences really associated with ADHD from those normally existing among sexes, the neuropsychological functioning of children with ADHD was also compared with that of control children. We expected to find substantial cognitive underperformance in children with ADHD, relative to typically developing children, across the evaluated cognitive domains, but minor differences between boys and girls with ADHD, based on the aforementioned inconsistencies observed in previous research.

2. Methods

2.1. Participants

Participants were 240 children aged 6–17 years ($M = 11.77$, $SD = 3.01$) divided into two groups: ADHD and control.

The ADHD group consisted of 65 boys and 55 girls ($M_{age} \pm SD = 11.09 \pm 2.93$ and 11.64 ± 3.32, respectively; $t(118) = -9.54$, $p = .342$) with a clinical diagnosis of ADHD, according to the DSM-IV criteria, all of whom were receiving psychological assistance in a private psychological clinic in Seville (Spain). Of these participants, 35% had a diagnosis of inattentive subtype and 65% had the combined subtype; moreover, 62.5% were using medication for ADHD, although this was withdrawn 24 h prior to neuropsychological evaluation. A description of participants' characteristics according to sex is provided in Table 1.

Table 1
Characteristics of participants with ADHD according to sex.

Variable	Boys ($n = 65$)	Girls ($n = 55$)
Age		
6–12 years	36	27
13–17 years	29	28
Mean (*SD*)	11.09 (2.93)	11.64 (3.32)
ADHD subtype	5 inattentive, 60 combined	37 inattentive, 18 combined
Medication		
None	23	22
IR-MPH	1	1
ER-MPH	22	19
IR + ER MPH	10	12
MR-MPH	3	1
Lisdexamfetamine	6	0
Comorbidities		
None	18	21
Oppositional defiant disorder	28	4
Specific learning disorder	17	28
Other	2	2

ADHD = attention-deficit/hyperactivity disorder, IR-MPH = immediate-release methylphenidate, ER-MPH = extended-release methylphenidate, MR-MPH = modified-release methylphenidate.

The control group comprised 60 boys and 60 girls ($M_{age} \pm SD = 12.28 \pm 2.82$ and 12.10 ± 2.91, respectively; $t(118) = -0.35$, $p = .727$) without ADHD or any other psychiatric or psychological disorder or learning disability. These children were recruited from secondary and elementary schools of the same regional area as that of children with ADHD.

2.2. Measures

Children's neuropsychological functioning was measured by the Wechsler Intelligence Scale for Children–Fourth Edition (WISC-IV; Wechsler, 2010). The WISC-IV, by means of 10 core tests, enables assessment of the children's performance in four domains: verbal comprehension, perceptive reasoning, working memory, and processing speed. The sum of the scores in these four areas or indices yields a total score indicative of the intellectual coefficient or overall cognitive performance level of each child.

2.3. Procedure

The assessment of participants with ADHD was partially conducted in the course of the clinical care provided to children attending the private Seville clinic. More specifically, children are usually assessed with the WISC-IV in the context of treated for ADHD in this clinic. However, the parents of the children included in this research were informed, prior to their children's assessment, of the researchers' objectives regarding the ongoing study and the opportunity to participate. The children's parents were thus free of choosing between: a) allowing their children's assessment and participation in the study; and b) allowing their children's assessment as part of the clinical care, but denying use of the data collected for the study. Individual administration of the assessment tasks was conducted over two sessions in the clinic and participants did not receive any kind of financial compensation.

Some of the control participants ($n = 69$) were referred to the private Seville clinic from their schools for their voluntary participation in the study and were assessed by the research team. Data of the remaining controls ($n = 51$) were directly provided by their schools because these children had already been assessed with the WISC-IV as part

of the academic protocol.

The study was conducted in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from the children's parents prior to the beginning of the study.

2.4. Data analyses

First, within the ADHD group, differences between boys and girls in ADHD subtypes, medication use, and comorbidities (presence/absence) were analyzed using Pearson's chi-square tests, and point-biserial correlations were calculated between subtypes and children's scores in the WISC-IV. Second, differences in performance scores between children with ADHD and controls, and between boys and girls within each group, were analyzed using Students' *t*-tests or Mann–Whitney *U* tests, depending on whether data met the parametric assumptions. Cohen's *d* was calculated as the effect size measure. Finally, given the large age range of the sample, to check whether age influenced the results, two-way ANOVAs—using robust methods (15% trimmed means) for non-parametric data—were conducted within each group, with sex and age range as factors. Two age ranges were defined: 6–12 years (n_{ADHD} = 63, $n_{Control}$ = 58) and 13–17 years (n_{ADHD} = 57, $n_{Control}$ = 62). Data analyses were conducted with the statistical software IBM SPSS 23.0, except for robust factorial ANOVAs that were conducted using the *Rstudio* 2.5.2. software, and statistical significance was set at $p < .05$.

3. Results

Boys and girls with ADHD did not significantly differ in medication use ($\chi2(1) = 0.27$, $p = .706$) or presence/absence of comorbidities ($\chi2(1) = 1.49$, $p = .245$), although they did differ in terms of ADHD subtypes ($\chi2(1) = 46.49$, $p < .001$). However, no significant point-biserial correlations were noted between ADHD subtypes and children's scores in the WISC-IV (correlation coefficients ranged from −0.14 to 0.11, all *p* values > .05).

The results of the Mann–Whitney *U* tests conducted for the total sample revealed significant differences between groups in neuropsychological performance (Table 2). Specifically, children with ADHD performed worse than controls in perceptual reasoning ($U = 3467.00$, $z = -6.96$, $p < .001$, $d = 1.00$), working memory ($U = 6082.00$, $z = -2.09$, $p = .037$, $d = 0.27$), and processing speed ($U = 2436.00$, $z = -8.89$, $p < .001$, $d = 1.39$). Additionally, they obtained a lower total WISC-IV score ($U = 3679.00$, $z = -6.55$, $p < .001$, $d = 0.93$). However, the comparisons between sexes within each group only revealed differences between boys and girls in perceptual reasoning within the ADHD group (Table 2). Girls with ADHD scored significantly lower than boys with ADHD in perceptual reasoning, with a medium effect size ($t(118) = 2.18$, $p = .032$, $d = 0.40$).

No significant main effects of sex or age range, and no interaction effects between sex and age, on performance scores of control children were revealed by robust factorial ANOVAs. In contrast, within the ADHD group, the results of the two-way ANOVAs showed significant main effects of age on verbal comprehension ($F(1, 116) = 21.29$, $p < .001$, $R^2 = 0.16$), perceptual reasoning ($F(1, 116) = 4.46$, $p = .035$, $R^2 = 0.04$), and total WISC-IV score ($F(1, 116) = 12.01$, $p = .001$, $R^2 = 0.09$). Specifically, younger children's (6–12 years) performance scores were higher than those of older children (13–17 years) in verbal comprehension ($M = 112.87$, $SD = 18.62$ vs. $M = 98.86$, $SD = 112.56$) and perceptual reasoning ($M = 98.51$, $SD = 13.77$ vs. $M = 93.09$, $SD = 13.76$), and they demonstrated higher overall cognitive performance ($M = 104.03$, $SD = 16.35$ vs. $M = 94.75$, $SD = 11.46$). However, a significant main effect of sex was still noted on perceptual reasoning ($F(1, 116) = 4.48$, $p = .036$, $R^2 = 0.04$), and no significant interaction effect between age and sex were noted on any variable.

Table 2
Differences between mean scores (SD) of children with ADHD and controls, and boys and girls, for each scale of the WISC-IV.

Scale	ADHD					Control					Comparisons between and within groups		
	Boys (n = 65)		Girls (n = 55)		Total	Boys (n = 60)		Girls (n = 60)		Total			
	Mean	*SD*	Mean	*SD*		Mean	*SD*	Mean	*SD*	Mean	*SD*	ADHD vs. Control	Boys vs. Girls
VC	107.57	18.31	104.62	16.39	106.22	107.78	6.45	107.08	7.03	107.43	6.73	$U = 6760.00$, $z = -0.82$, $p = .412$, $d = 0.11$	ADHD: 0.92[a] (−3.38, 9.28), $p = .358$, $d = 0.17$ Control: 1737.50[b] (−0.33), $p = .741$, $d = 0.06$
PR	98.45	15.06	92.96	12.03	95.93	106.53	6.48	106.88	7.54	106.71	7.00	$U = 3467.00$, $z = -6.96$, $p < .001$, $d = 1.00$	ADHD: 2.18[a] (0.49, 10.47), $p = .032$, $d = 0.40$ Control: 1742.00[b] (−0.31), $p = .759$, $d = 0.06$
WM	105.83	18.19	104.69	14.76	105.31	109.03	5.98	109.28	6.53	109.16	6.24	$U = 6082.00$, $z = -2.09$, $p = .037$, $d = 0.27$	ADHD: 0.37[a] (−4.92, 7.20), $p = .710$, $d = 0.07$ Control: 1733.00[b] (−0.36), $p = .722$, $d = 0.06$
PS	92.97	14.78	95.58	13.61	94.17	109.37	5.30	108.32	6.40	108.84	5.88	$U = 2436.00$, $z = -8.89$, $p < .001$, $d = 1.39$	ADHD: −1.00[a] (−7.79, 2.56), $p = .319$, $d = -0.18$ Control: 1678.50[b] (−0.65), $p = .519$, $d = 0.12$
Total	100.85	16.63	98.18	12.61	99.63	110.07	6.25	109.92	7.37	109.99	6.80	$U = 3679.00$, $z = -6.55$, $p < .001$, $d = 0.93$	ADHD: 0.97[a] (−2.75, 8.08), $p = .332$, $d = 0.18$ Control: 1703.50[b] (−0.51), $p = .612$, $d = 0.09$

ADHD = attention-deficit/hyperactivity disorder, WISC-IV = Wechsler Intelligence Scale for Children—Fourth Edition, VC = verbal comprehension, PR = perceptual reasoning, WM = working memory, PS = processing speed.
[a] Student's *t*-test (95% confidence interval).
[b] Mann–Whitney *U* test (*z* score).

4. Discussion

By conducting this study, we aimed to evaluate the differences between boys and girls with ADHD in terms of their levels of neuropsychological functioning. The results revealed cognitive performance scores lower than those of controls among boys and girls with ADHD, which suggests neuropsychological impairments in both sexes—but there were no significant differences among them in almost any of the evaluated functional domains. According to these results, boys and girls with ADHD exhibit similar patterns of cognitive performance, both generally and in the specific domains of verbal comprehension, working memory, and processing speed. However, girls with ADHD demonstrated a lower facility for perceptual reasoning than boys with this disorder. Children's age cannot account for these differences because, despite some age effects on children's performance scores, no interactions of age with sex were observed in any neuropsychological variable. Likewise, these differences between boys and girls with ADHD are not derived from normally existing differences among sexes in neuropsychological functioning, as these were not observed within the control group.

The neuropsychological underperformance shown by children with ADHD compared to controls, besides confirming our starting hypothesis, lends support to the considerable background of scientific literature available in this regard. In particular, neuropsychological deficits, both in general or in specific cognitive domains, have been observed among children with ADHD in numerous studies (e.g., Fenollar-Cortés et al., 2015; Krieger and Amador-Campos, 2018; Li et al., 2017). Therefore, the large differences noted in this study between children with ADHD and controls in perceptual reasoning, working memory, processing speed, and overall cognitive performance are not surprising. Also, the few differences this study identified between boys and girls with ADHD, which were limited to their scores in perceptual reasoning, support the findings of earlier studies, in which few differences were observed at the neuropsychological level (Seidman et al., 2005; Wodka et al., 2008; Yang et al., 2004). Indeed, in the study conducted by Yang et al. (2004), the performance scores of boys and girls with ADHD differed only on the block design subtest, a measure of perceptual reasoning, with girls attaining lower scores than boys.

As for the rest of the abilities assessed by the WISC-IV, some discrepancies between our results and those produced by other studies can be observed. For instance, although some authors reported similar performance of working memory in boys and girls (O'Brien et al., 2010), others suggested lower vocabulary scores—related to verbal comprehension functioning—in girls and worse processing speed in boys (Rucklidge and Tannock, 2001). The greater intellectual impairment in girls with ADHD (relative to boys) indicated by the results of some investigations (Gaub and Carlson, 1997; Gershon, 2002; Rucklidge, 2010) is not borne out by our results, in terms of total scores on the WISC-IV, an index of overall cognitive or intellectual ability. However, this last discrepancy may be explained by the differences between fluid intelligence and crystallized intelligence, and the extent to which fluid intelligence relates to perceptual reasoning (Thaler et al., 2015).

In effect, the lower performance of girls with ADHD on perceptual in this study merits consideration in future studies, because this finding may have significant implications for clinical practice, largely on the basis of the relationship between this result and reasoning or fluid intelligence (Thaler et al., 2015), which is involved in the innate ability to face new tasks or problems. Our results may therefore indicate heightened difficulties for girls with ADHD, relative to boys with this disorder, when facing new tasks to which they cannot apply prior knowledge. Such difficulties may not always be reflected in poorer performance of girls with ADHD on neuropsychological tasks, relative to boys, nor do the results imply a greater intellectual impairment among these girls than boys, in terms of their crystallized intelligence or ability to apply acquired knowledge in daily practice. This, in sum, is especially relevant for the design of intervention strategies facilitating the improvement of neuropsychological deficits shown by girls with ADHD and their learning problems. Differences between boys and girls with ADHD inhere more in certain kinds of intelligence or cognitive abilities that are required to follow specific action procedures.

Nevertheless, this study suffers from some limitations that must be taken into account when interpreting our findings. Boys and girls with ADHD did not significantly differ from each other in medication use and the presence/absence of comorbidities. However, the cross-sectional evaluation conducted in this study does not allow an examination of whether medication and comorbidities impact the performance of both sexes equally, in the long term. Similarly, although ADHD inattentive and combined subtypes did not correlate with children's performance scores, previous studies underlined some differences among subtypes in cognitive performance (Li et al., 2017; Mayes et al., 2009; Thaler et al., 2013; Yang et al., 2013). A longitudinal neuropsychological evaluation of boys and girls with ADHD might also have facilitated a careful analysis of the impact of predominant ADHD symptoms across development and further exploration of any potential age effects on neuropsychological functioning. The latter both in relation to sex differences in ADHD and the neuropsychological deficits shown by children with this disorder relative to their peers.

5. Conclusions

First, the results of this study, despite indicating cognitive underperformance of children with ADHD compared to typically developing children, do not show large differences between boys and girls with ADHD in this regard, a result which would have indicated different neuropsychological profiles for the two sexes. As such, the study emphasizes the need to address the cognitive impairments that girls with ADHD might present (and that could affect their academic performance) without unduly discriminating between the sexes on the basis of the perceived prevalence of the disorder. This is especially true given the absence of significant differences between boys and girls in the domains of processing speed and working memory—skills in which these children have often presented difficulties in comparison with their non-ADHD peers (e.g., Fenollar-Cortés et al., 2015; Krieger and Amador-Campos, 2018).

Second, the lower scores that girls with ADHD obtained on this study's perceptual reasoning task may indicate a lower level of fluid intelligence in these girls, relative to boys with ADHD. This may point to the presence of deficits in girls with ADHD, in terms of their ability to confront and solve new tasks; deficits in this area may account for the greater learning problems prior research identified in these girls, relative to their peers. Future studies should replicate these results by analyzing the differences between boys and girls with ADHD accounting for possible interaction effects of medication, comorbidities, age and sex on their long-term neuropsychological functioning. However, our findings highlight the importance of paying more attention to the academic difficulties faced by girls with ADHD. They also support the implementation of intervention programs targeted at enhancing fluid intelligence and perceptual reasoning as the appropriate method of improving the school performance of these girls.

Conflict of interest

The authors have no conflicts of interest to declare.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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