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Gender Differences in the Comorbidity of ADHD Symptoms and Specific Learning Disorders in a Population-Based Sample

Julia Kerner auch Koerner [1,2,*,†], Linda Visser [2,3,†], Josefine Rothe [4], Gerd Schulte-Körne [5] and Marcus Hasselhorn [2,3]

[1] Educational Psychology, Helmut-Schmidt-University Hamburg, 22043 Hamburg, Germany
[2] Center for Research on Individual Development and Adaptive Education of Children at Risk (IDeA), 60323 Frankfurt am Main, Germany; linda.visser@dipf.de (L.V.); hasselhorn@dipf.de (M.H.)
[3] Department of Education and Human Development, DIPF | Leibniz Institute for Research and Information in Education, 60323 Frankfurt am Main, Germany
[4] Department of Child and Adolescent Psychiatry, Faculty of Medicine, Technische Universität Dresden, 01307 Dresden, Germany; josefine.rothe@uniklinikum-dresden.de
[5] Department of Child and Adolescent Psychiatry, Psychosomatic and Psychotherapy, Ludwig-Maximilian-University Munich, 80336 Munich, Germany; gerd.schulte-koerne@med.uni-muenchen.de
* Correspondence: KernerAuchKoerner@hsu-hh.de
† These authors share first authorship.

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Abstract: Children with attention deficit hyperactivity disorder (ADHD) often exhibit comorbid specific learning disorders. In clinical samples, comorbidity in girls with ADHD tends to be more common than in boys with ADHD. However, this is not the case in studies of random samples. In this paper gender differences in the comorbidity of ADHD symptoms and learning disorders in reading, spelling and math are explored in a population-based sample of 2605 3rd and 4th graders (1304 girls) without symptoms of ADHD and 415 (141 girls) with symptoms of ADHD. Girls with ADHD symptoms had higher ratios of comorbid math disorders than boys with ADHD symptoms, but not with reading or spelling disorders. Math achievement was predicted by gender and by symptoms of inattention. Girls with ADHD symptoms and math disorders received the same amount of additional support from teachers or therapists as boys with ADHD symptoms and math disorders. Our results highlight the importance of exploring the increased comorbidity of specific learning disorders in children with ADHD symptoms and especially with math disorders in girls with ADHD symptoms. Implications for providing suitable interventions and preventing the accumulation of academic problems are discussed.

Keywords: ADHD; specific learning disorders; reading disorders; spelling disorders; math disorders; dyslexia; dyscalculia; sex differences; teacher support; academic achievement

1. Introduction

Approximately one in 20 children are affected by attention deficit hyperactivity disorder (ADHD [1,2]), showing age-inappropriate symptoms of inattention, hyperactivity and impulsivity [3,4]. These children often suffer from not only ADHD symptoms but also poor school achievement [5], impaired health [6], low quality of life [7] and low self-esteem [8]. ADHD leads to more negative family interactions [8], and children with ADHD often are less popular among their peers than children without ADHD [9]. Moreover, the costs of ADHD for the health system are considerable [10–12] and rise through comorbid conditions [13].

1.1. Gender Differences in ADHD

Huss, Hölling, Kurth and Schlack [1] reported that boys receive an ADHD diagnosis approximately four times more often than girls. However, when taking symptoms above a clinical cut-off as the criterion, boys were affected only 1.77 times more than girls [1]. Thus, the gender ratio is more unequal in clinical studies (i.e., more boys) than in epidemiological studies (i.e., similar numbers of boys and girls [14]).

Meta-analyses on gender differences in children with ADHD have repeatedly reported lower ratings of hyperactivity, impulsivity and inattention in girls with ADHD compared to boys with ADHD [14,15]. Girls with ADHD more often are diagnosed with the inattentive subtype of ADHD [16] and children diagnosed with inattention as a subtype of ADHD more often are female [17]. Therefore, inattention is more pronounced and hyperactivity and impulsivity less pronounced [16] in girls with ADHD than in boys with ADHD. Furthermore, girls with ADHD, as well as girls without ADHD, tend to have more internal symptoms and fewer external symptoms [15,18]. Since inattention combined with little or no hyperactivity/impulsivity seldom leads to disruptive behavior in the classroom, children suffering from the inattentive subtype of ADHD may be overlooked [15] when referrals are being made for testing. This might explain the referral bias [19], in which boys are referred for testing for ADHD more often than girls, who are referred only if they show severe impairment (i.e., more severe symptoms of ADHD or multiple comorbid symptoms). This is supported by the finding that some gender differences are moderated by referral source (i.e., clinic vs. population based). In population-based samples, girls with ADHD show less impairment than boys with ADHD and in clinic-referred populations, girls and boys with ADHD show similar levels of impairment [14,15]. Therefore, it is important to keep the source of the sample (i.e., clinic vs. population-based) in mind when addressing gender differences in ADHD.

1.2. ADHD and Specific Learning Disorder

Children with ADHD often suffer from specific learning disorders. Specific learning disorders are characterized by persistently low achievement scores in key academic skills (reading, spelling, math). Low achievement scores generally are defined as greater than 1.5 standard deviations below age mean or grade level. However, in the large number of studies conducted in this area, specific learning disorders are characterized inconsistently. For example, scores with at least 1 standard deviation below the mean are also often used [20–22]. This is in line with the World Health Organization's classification systems ICD-10 [4] and ICD-11 [23], which require a discrepancy of at least one standard deviation between specific learning performance and intellectual achievement. While the Diagnostic and Statistical Manual of Mental Disorders (DSM-5 [3]) no longer requires this, intellectual disability still must be excluded. In addition, studies have differed also in how they measure reading, spelling and math skills (e.g., reading comprehension vs. reading fluency, spelling words in blank spaces vs. writing dictated texts).

In referred samples of children with ADHD, estimates of the prevalence of specific learning disorders range from 39% [24] to 65% [25] for reading, 30% [25] to 62% for spelling [26] and 30% [26] to 31% [25] for math. In population-based samples of children with ADHD the rates of learning disorders are 15% to 51% for reading [24,27,28], 31 to 42% for spelling [28] and 24 to 34% for math [28]. Hence, there is greater prevalence of specific learning disorders in children with ADHD than in children in the general population, which is 2 to 8% [29–32]. The comorbidity of ADHD and reading disorders seems to be due largely to genetic influence [33,34]. In contrast, for the comorbidity of ADHD and math disorders there is evidence of independent familial transmission [35].

1.2.1. Gender Differences in the Comorbidity of ADHD and Specific Learning Disorders

In a meta-analysis of ADHD and academic achievement in reading, spelling and math no gender differences in ADHD samples were found [5]. Similarly, Capano and colleagues [21] did not find gender differences in math disorders in a clinical ADHD sample. Further, in a population-based study in which disorders in reading, spelling and math were compared no gender differences were found either ([28]; odds ratios from 0.8 to 1.3). However, in a population-based study of reading and spelling disorders and their correlation to ADHD girls with reading and spelling disorders had nearly double the chance of suffering from ADHD than boys [27,36]. Similar results were reported by Czamara and colleagues [37] from another population-based study in which girls with ADHD had a greater risk of suffering from reading and/or spelling disorders than boys with ADHD. In summary, studies of gender differences in the association between ADHD and specific learning disorders are scarce and the few results available are heterogeneous. While in some studies no gender differences are found, in others specific learning disorders are found to be more prevalent in girls with ADHD than in boys with ADHD.

1.2.2. Differential Associations between ADHD Symptoms and Specific Learning Disorders

Specific learning disorders are more strongly associated with symptoms of inattention than with symptoms of hyperactivity or impulsivity. For example, inattention has been found to be related to reading achievement, but not to hyperactivity or impulsivity [38]. Children with the inattentive subtype of ADHD tend to have a comorbid specific learning disorder more often [17] and obtain lower scores in reading, spelling and math over time [39] than children with the combined subtype of ADHD. In a large sample of twins and their singleton siblings, children with the inattentive and combined subtype required more remedial help in reading than children with the hyperactive/impulsive subtype [40]. Results of behavioral genetic studies indicate that the bivariate heritability of reading disorders and inattention is significant, whereas the bivariate heritability of reading disorders and hyperactivity/impulsivity is minimal [41]. Furthermore, ADHD symptoms account for the relationship between specific learning disorders and external and internal symptoms [42].

Overall, the relationship between ADHD symptoms and specific learning disorders seems to be influenced by gender. In a community sample of twins, those with reading disorders were more likely to meet criteria for diagnosis of ADHD. While inattention was associated with reading disorders in both girls and boys, hyperactivity and impulsivity were associated with reading disorders in boys only [43]. Children with the inattentive subtype are more likely to be female and to suffer from specific learning disorders as well [17].

1.3. Research Questions and Hypotheses

Most studies addressing the relationship between ADHD symptoms and specific learning disorders have been conducted of clinical samples that have been preselected because of their ADHD diagnosis or diagnosed specific learning disorders. Due to referral bias (i.e., boys are referred for testing more often, and girls are referred only when they show great impairment) studies of gender differences might be biased in clinical populations. Additionally, due to the larger proportion of boys in ADHD samples, the group of girls with ADHD often is too small to draw reliable conclusions, especially when trying to compare girls with ADHD and comorbid specific learning disorders to those with ADHD but no learning disorders. Studies of ADHD and learning disorders have focused mostly on reading disorders. Very few studies have been conducted of problems in reading, spelling and math in children with ADHD symptoms in the same population-based sample [28,37]. Thus, we address the following research questions:

1. Do girls with ADHD symptoms experience specific learning disorders more often than girls without ADHD symptoms? We expect girls with ADHD symptoms to have more specific learning disorders in reading, spelling and/or math than girls without ADHD symptoms.
2. Do girls with ADHD symptoms experience specific learning disorders more often than boys with ADHD symptoms? We expect girls with ADHD symptoms to experience learning disorders in reading, spelling and/or math more often than boys with ADHD symptoms.

3. Are gender differences in the prevalence of learning disorders in reading, spelling and/or math due to differences in the severity of symptoms of inattention, hyperactivity and impulsivity? We do not expect gender to predict performance in reading, spelling and /or math when inattention, hyperactivity and impulsivity are considered.
4. Do girls with ADHD symptoms and specific learning disorders receive less additional support from a teacher or (special education) therapist than boys with ADHD symptoms and specific learning disorders? From informal observations, we expect girls with ADHD symptoms and specific learning disorders to receive less support than boys with ADHD symptoms and specific learning disorders.

2. Materials and Methods

2.1. Participants and Procedure

The data analyzed in this study were gathered in an online study in Germany in 2017. We invited families with children in grade 3 and/or grade 4 in the two German federal states of Hesse (through the Hessian Ministry of Culture; *n* = 25,000) and Bavaria (addresses provided by local registration offices; *n* = 27,734) to participate in this study. The families were chosen randomly so that the sample would be representative of the population in terms of gender and age (8.8–10.8 years; Bavaria) or grade (Hesse).

The invitation letter contained instructions and login data for the application (app), which could be downloaded onto a tablet or smartphone to provide information on and to assess the academic skills and psychopathological profile of the children within eight weeks. In total, 4542 families logged into the app. All parents and children gave their informed consent to participate. The study was approved by the ethics committees of the University Hospital of the Ludwig-Maximilians-University Munich and the DIPF | Leibniz Institute for Research and Information in Education, Frankfurt am Main. All subjects gave written informed consent in accordance with the Declaration of Helsinki.

After confirming informed consent and agreement with the policies on data protection, the children completed academic achievement tests, an intelligence test and questionnaires about psychopathological symptoms. These tasks were distributed over four days and took approximately 45 min per day to complete. A parent answered questions about his/her child and the family which focused on, for example, educational and migration background, family language and school-related problems and diagnoses of the child. One of the questions addressed whether extracurricular support for learning disorders was provided or not. The parent also completed questionnaires about the child's psychopathological symptoms including ADHD. For more information about the online study, we refer to Visser and colleagues [44].

We excluded cases in which the parent indicated the child had had a diagnosis related to visual impairment (including eye infections, congenital conditions and other types of visual impairment; *n* = 24), hearing impairment (including otitis media, congenital ear conditions and other types of hearing problems.; *n* = 44), neurological disease (including conditions of the nerves and (central) nervous system, musculoskeletal system, cerebral palsy and other paralysis syndromes; *n* = 33), or a chromosomal defect (*n* = 1). We also excluded cases in which the nonverbal intelligence quotient was 70 or lower (*n* = 81). This quotient was based on the first three scales of the German culture fair intelligence test (CFT 20-R; [45]), which was normed using the test results of the online study sample. In cases (*n* = 49) where two siblings had participated, we randomly excluded one of them to prevent dependencies within the sample. Finally, we conducted plausibility checks based on data-based cut-offs for the total testing time, response time and response type (e.g., too many repetitions of the same answer on the reading test; for more information see Visser and colleagues [44]. We excluded cases with incomplete or implausible data regarding intelligence (*n* = 76 and *n* = 314), math performance (*n* = 380 and *n* = 179), spelling performance (*n* = 582 and *n* = 53), reading performance (*n* = 665 and *n* = 45) or ADHD (*n* = 638 incomplete). Due to the overlap in reported excluded cases, these numbers do not add up. In addition, the numbers for the incomplete data are cumulative because the children completed the tests sequentially and consequently, data were missing for all tests from a certain moment onwards in cases of quitting.

The final sample consisted of 3020 children with a mean age of 9 years and 0 months (range 8;0 to 11;0). There were 1575 boys and 1445 girls, 2843 (94.1%) of the children had German nationality and 2720 (90.1 %) did speak German as dominant language. Appendix A includes information about the education of the children's mothers as an indication of the family's socioeconomic status (SES). It appears that the mothers of children with ADHD symptoms and/or specific learning disorders tended to have a low educational level. For more detailed information about the representativeness of the sample, we refer to Visser and colleagues [44].

2.2. Material

The tests and questionnaires administered in this online study are all widely used in Germany. We converted them from their original paper-pencil format into online versions except for the math performance test, which already was an online test. For all learning performance tests, we developed separate norms for each grade based on the full sample of the online study.

Reading performance was assessed using the Wuerzburger silent reading test –revised (WLLP-R; [46]), which was designed to measure the reading fluency of children in grades 1 to 4. On this test, children choose one of four pictures that depicts a written word. The test contains 180 items, and test takers are given five minutes to complete as many as possible. The original paper-pencil version has been tested for reliability (retest 0.82 and 0.80 for grades 3 and 4, respectively) and validity (correlations of 0.72 to 0.79 with another German reading test).

Spelling performance was assessed using the Weingartner basic vocabulary spelling test for grades 3 (WRT 3+; [47]) and 4 (WRT 4+; [48]). This is a dictation in which children spell words in blank places in a text. The WRT 3+ contains 55 items and the WRT 4+ contains 60 items. Both test versions take approximately 45 min to complete. For the paper-pencil versions, the internal consistency and retest reliability are over 0.90 and validity has been supported by strong correlations with external criteria including average school grades for dictations ($r > 0.70$).

The CODY test [49] is an online test for assessing the basic mathematical and counting competences of children in grades 2 to 4. It contains subtests for assessing basic number processing (counting, magnitude comparisons), complex number processing (number dictation, number line, domino count comparison, missing numbers), counting skills (addition, subtraction, multiplication, placeholder tasks) and visuo-spatial working memory (matrix memory span). The total testing time is approximately 45 min. The manual reports a retest reliability of 0.88 for the total test and correlations of 0.73–0.83 with the results of other German math tests.

To assess ADHD symptoms, we administered the parent rating scale for ADHD (FBB-ADHS) which is part of the Diagnostic System of Mental Disorders for Children and Adolescents–II (DISYPS-II; [50]). This questionnaire contains 20 items: nine about inattention, seven about hyperactivity and four about impulsivity. Parents rated on four-point Likert scales ranging from *not at all* (0) to *particularly* (3) the extent to which their children exhibited these three symptoms of ADHD. The internal consistency of the paper-pencil version is 0.94 for the complete scale and 0.81–0.91 for the three subscales. We compiled non-gender-specific and gender-specific norms based on the data from the online study sample.

Extracurricular support for learning disorders was assessed with one item on the parent questionnaire, which reads as follows: *Does your child receive extracurricular support within or outside the school?* (in German: *Erhält Ihr Kind schulische oder außerschulische Förderung?*). Parents could answer either *yes* or *no*.

2.3. Data Analysis

We formed groups of children according to whether or not they had learning disorders in reading, spelling and/or math as indicated in their results on the WLLP-R, WRT 3+/4+ and CODY test, respectively. We used a cut-off of one standard deviation below the mean for defining specific learning disorders. In addition, we created a variable indicating whether a child had learning disorders in one or more of the three areas, or no learning disorders.

Next, we formed groups of children according to ADHD symptoms. We tested the ADHD questionnaire for measurement invariance across genders. If measurement invariance was confirmed, we used non-gender-specific norms for grouping the children. We used a cut-off percentile of $\geq$90 / z-score $\geq$1.28 ([50], p. 102) to identify ADHD. In addition, the average item score for the items used to measure inattention was used as a continuous variable in the analyses. The same applies to the items used to measure hyperactivity and impulsivity.

We calculated descriptive statistics on average ADHD symptoms scores for girls and boys according to age (8 to 11). To answer research questions 1 and 2, we identified the number and percentage of children with learning disorders in reading, spelling and math, and of those with or without any learning disorders, separately for boys and girls with and without ADHD symptoms. Subsequently, we tested the differences between the size of these subgroups using the odds ratio and Fisher's Exact Test. In addition, we produced Venn diagrams to visualize these subgroups.

To answer research question 3, we calculated the mean scores of responses to the items concerning inattention, hyperactivity, impulsivity and to items on the ADHD questionnaire separately for boys and girls with and without ADHD. Differences between the subgroups were tested using the Mann–Whitney U test (because of right-skewed data). In addition, linear regression analyses were performed with the learning achievement score (for reading, spelling and math, separately) as the dependent variable and gender as the independent variable. The average item scores for inattention, hyperactivity and impulsivity were added stepwise as predictors in the analyses and their interactions with each other and with gender. In cases where the regression estimates for gender changed by more than 10% when adding the ADHD symptom scores to the model, we concluded that these ADHD symptoms confounded the relationship between gender and learning achievement.

Descriptive statistics on how many children received support according to their parents were derived to address research question 4. Differences between children with and those without ADHD symptoms and/or specific learning disorders and between girls and boys were tested using Fischer's Exact Test.

RStudio Version 1.3.1093 [51] was used for data analyses and false discovery rate (FDR) correction [52] was applied to correct multiple testing.

3. Results

3.1. Descriptive Statistics

Table 1 shows mean scores and standard deviations of inattention, hyperactivity and impulsivity subscales, separately for boys and girls aged 8 to 11, as well as the results of the Mann-Whitney U test. It is important to note that the sample consisted of children in grades 3 and 4, meaning some of the 11-year-olds might have repeated a grade and therefore might have had a greater chance of developing behavioral problems. For the 8- to 10-year-olds, the severity of symptoms differed significantly between girls and boys, except for impulsivity at age 10. For age 11, the insignificant results are not conclusive due to the small sample sizes.

Table 1. Age Differences in Severity of Symptoms.

		Girls			Boys			MWU
	Age	*n*	*M*	*SD*	*n*	*M*	*SD*	W (*p*)
inattention	8	251	0.61	0.53	254	0.84	0.59	39,936 (<0.001) *
inattention	9	724	0.55	0.54	766	0.73	0.58	340,398 (<0.001) *
inattention	10	461	0.53	0.51	547	0.73	0.58	156,260 (<0.001) *
inattention	11	8	0.69	0.94	8	1.04	0.69	46 (0.155)
hyperactivity	8	251	0.28	0.44	254	0.44	0.52	39,915 (<0.001) *
hyperactivity	9	724	0.23	0.40	766	0.39	0.47	343,534 (<0.001) *
hyperactivity	10	461	0.22	0.37	547	0.33	0.49	146,546 (<0.001) *
hyperactivity	11	8	0.43	0.93	8	0.54	0.64	45 (0.180)
impulsivity	8	251	0.48	0.58	254	0.66	0.66	37,364 (0.001) *
impulsivity	9	724	0.50	0.57	766	0.62	0.64	307,841 (<0.001) *
impulsivity	10	461	0.48	0.55	547	0.58	0.65	136,929 (0.016)
impulsivity	11	8	0.78	1.00	8	1.00	0.68	42 (0.337)

* significant after FDR correction; MWU = Mann-Whitney U test.

3.2. Gender Differences in the Comorbidity of ADHD Symptoms and Specific Learning Disorders

Strong measurement invariance is a prerequisite for comparing means between groups [53]. A multiple group confirmatory factor analysis revealed strong measurement invariance of the FBB-ADHS in relation to gender (see Appendix B). Therefore, all further analyses are based on normed scores for ADHD symptoms that are not gender specific.

Table 2 shows the numbers and percentages of girls and boys with and without ADHD symptoms and those with and without specific learning disorders. The right side of the table contains the results of Fisher's Exact Test including the odds ratio and its 95% confidence interval (in brackets). For both boys and girls, ADHD symptoms were related to higher rates of specific learning disorders in all three areas. Within the group of children with ADHD, girls more often had learning disorders in math. The overlap between the various types of learning disorders and ADHD symptoms is visualized in Figures 1 and 2.

Table 2. Frequency of Specific Learning Disorders in Boys/Girls With/Without ADHD Symptoms and Fisher's Exact Test Results.

Learning Disorders	Boys			Girls			Fisher's Exact Test: Compare		
	No ADHD	ADHD	Total	No ADHD	ADHD	Total	Boys with/without ADHD	Girls with/without ADHD	Girls/Boys with ADHD
none (n)	981	92	1073	972	35	1007			
none (%)	70.3	51.1	35.5	71.9	37.2	33.3			
reading (n)	215	45	260	164	22	186	OR = 1.83 (1.24–2.67)	OR = 2.21 (1.27–3.72)	OR = 0.92 (0.48–1.7)
reading (%)	15.4	25	8.6	12.1	23.4	6.2	$p = 0.002$ *	$p = 0.004$ *	$p = 0.882$
spelling (n)	211	57	268	145	31	176	OR = 2.6 (1.8–3.72)	OR = 4.09 (2.48–6.62)	OR = 1.06 (0.6–1.86)
spelling (%)	15.1	31.7	8.9	10.7	33	5.8	$p < 0.001$ *	$p < 0.001$ *	$p = 0.892$
math (n)	164	41	205	224	39	263	OR = 2.21 (1.47–3.29)	OR = 3.56 (2.24–5.61)	OR = 2.4 (1.35–4.26)
math (%)	11.8	22.8	6.8	16.6	41.5	8.7	$p < 0.001$ *	$p < 0.001$ *	$p = 0.002$ *
any (n)	413	88	501	377	59	436	OR = 2.27 (1.64–3.15)	OR = 4.34 (2.76–6.92)	OR = 1.76 (1.03–3.04)
any (%)	29.6	48.9	16.6	27.9	62.8	14.4	$p < 0.001$ *	$p < 0.001$ *	$p = 0.031$
total (n)	1395	180	1575	1351	94	1445			

* significant after FDR correction; OR = odds ratio.

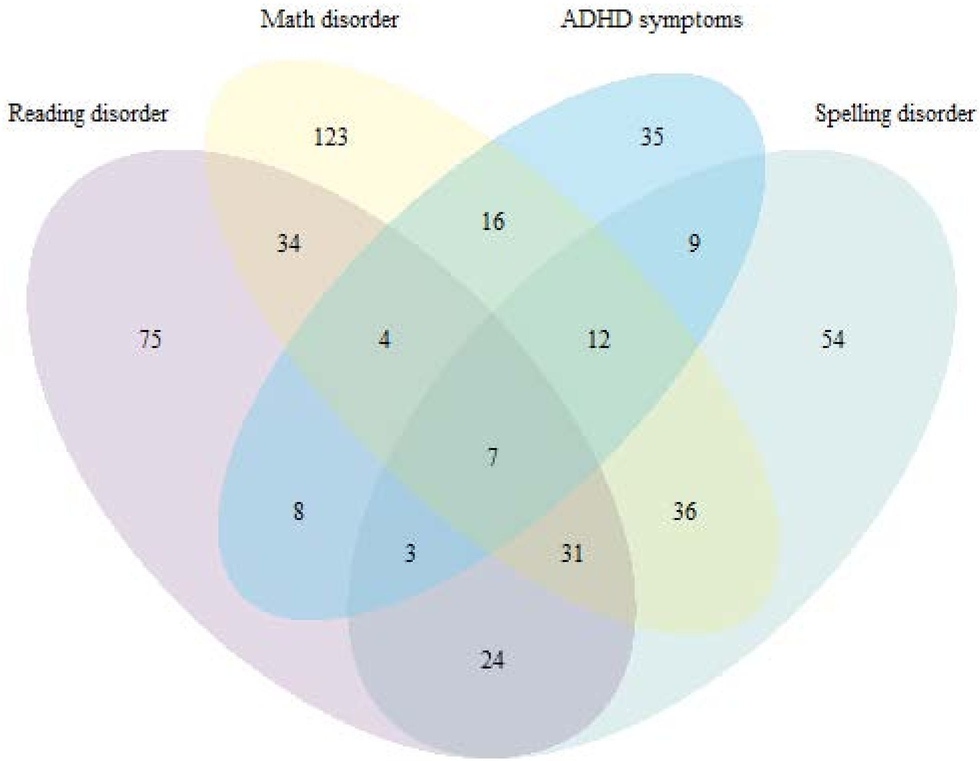

Figure 1. Venn diagram for girls.

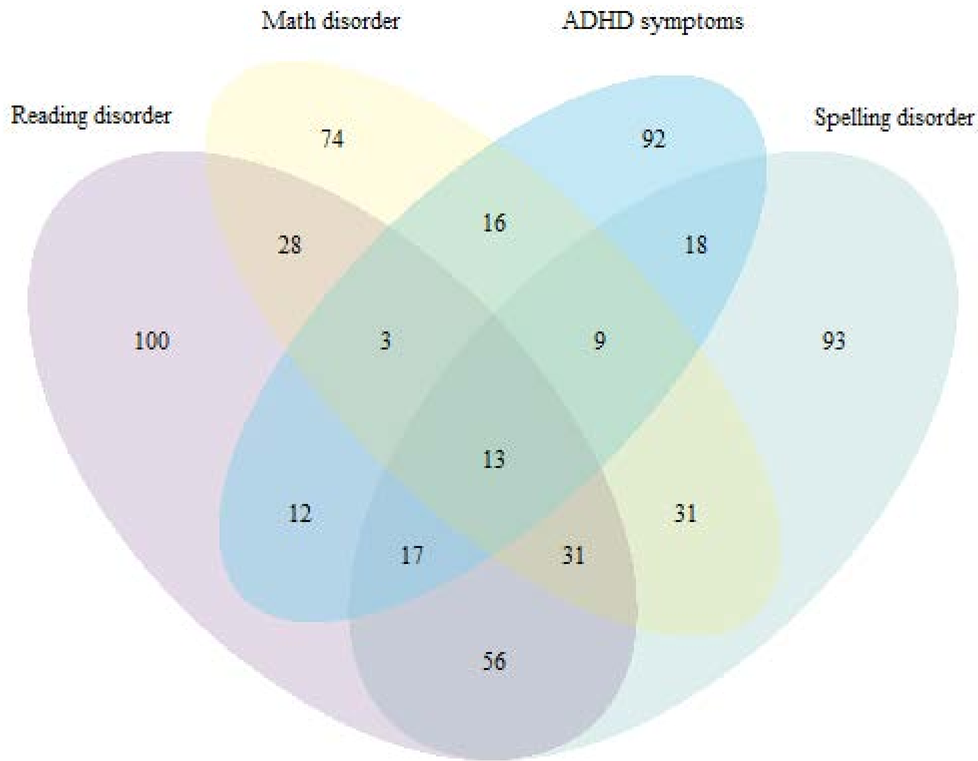

Figure 2. Venn diagram for boys.

3.3. The Role of ADHD Symptoms

Table 3 contains means and standard deviations of the subscales for inattention, hyperactivity, impulsivity and the total ADHD questionnaire, separated for boys and girls with and without ADHD symptoms. Boys had higher scores for all ADHD symptoms. The symptom scores were not significantly different between boys and girls with ADHD.

Table 3. Average Item Scores on ADHD Questionnaire for Girls and Boys with and without ADHD.

	Boys (*M* (*SD*))			Girls (*M* (*SD*))			MWU (*W* (*p*)): Compare	
	No ADHD (n = 1395)	ADHD (n = 180)	Total (n = 1575)	no ADHD (n = 1351)	ADHD (n = 94)	Total (n = 1445)	Girls/Boys with ADHD	Girls/Boys (Total Sample)
Inattention	0.62 (0.43)	1.8 (0.53)	0.75 (0.58)	0.47 (0.41)	1.78 (0.58)	0.55 (0.53)	8780 (0.607)	1,404,022 (<0.001) *
Hyperactivity	0.25 (0.29)	1.34 (0.61)	0.38 (0.49)	0.16 (0.23)	1.36 (0.6)	0.24 (0.4)	8446 (0.982)	1,379,534 (<0.001) *
Impulsivity	0.48 (0.5)	1.62 (0.75)	0.61 (0.64)	0.41 (0.47)	1.6 (0.71)	0.49 (0.57)	8468 (0.991)	1,264,458 (<0.001) *
ADHD total	0.46 (0.3)	1.6 (0.37)	0.59 (0.47)	0.35 (0.27)	1.6 (0.42)	0.43 (0.42)	8900 (0.479)	1,411,482 (<0.001) *

ADHD = symptoms of ADHD; MWU = Mann-Whitney U test; * significant after FDR correction; items contain a 4-point Likert scale from 0 to 3.

In Table 4 the results are presented of the regression analyses with learning achievement (in math, reading and spelling) as the dependent variable and gender (model 1), plus inattention (model 2), plus hyperactivity (model 3), plus impulsivity (model 4) as the predictors. In contrast to hyperactivity and impulsivity, inattention appears to play a confounding role in that the estimate for gender decreases by more than 10% when inattention is considered. For reading and spelling performance, inattention accounts fully for the relationship to gender, as gender no longer is a significant predictor when inattention is considered.

In the model for predicting spelling ability, the addition of hyperactivity as a predictor lowers the estimate for gender by 24%. This might be explained by an interaction between inattention and hyperactivity (see Appendix C, although this interaction is no longer significant after applying the FDR correction).

Table 4. Results of the Regression Analyses for Predicting Learning Achievement Based on Gender, Inattention (inatt), Hyperactivity (hyp) and Impulsivity (imp) Symptoms.

		Math		Reading		Spelling	
	Predictor	Estimate (*p*)	% Estimate Change	Estimate (*p*)	% Estimate Change	Estimate (*p*)	% Estimate Change
model 1	gender	−0.24 (<0.001) *		0.161 (<0.001) *		0.156 (<0.001) *	
model 2	gender	−0.361 (<0.001) *	50	0.072 (0.040)	55	0.049 (0.156)	69
	inatt	−0.566 (<0.001) *		−0.379 (<0.001) *		−0.478 (<0.001) *	
	gender x inatt	−0.085 (0.158)		−0.137 (0.028)		−0.13 (0.033)	
model 3	gender	−0.363 (<0.001) *	1	0.067 (0.057)	7	0.037 (0.284)	24
	inatt	−0.679 (<0.001) *		−0.46 (<0.001) *		−0.492 (<0.001) *	
	hyp	0.11 (0.103)		0.047 (0.507)		−0.098 (0.156)	
	gender x inatt	−0.048 (0.533)		−0.112 (0.162)		−0.113 (0.151)	
	gender x hyp	−0.049 (0.618)		−0.028 (0.781)		−0.017 (0.866)	
	inatt x hyp	0.116 (0.015)		0.116 (0.019)		0.132 (0.007)	

Table 4. *Cont.*

		Math		Reading		Spelling	
	Predictor	**Estimate (*p*)**	**% Estimate Change**	**Estimate (*p*)**	**% Estimate Change**	**Estimate (*p*)**	**% Estimate Change**
model 4	gender	−0.364 (<0.001) *	0	0.066 (0.06)	2	0.037 (0.288)	1
	inatt	−0.71 (<0.001) *		−0.491 (<−0.001) *		−0.521 (<0.001) *	
	hyp	0.1 (0.214)		−0.003 (0.971)		−0.141 (0.088)	
	imp	0.092 (0.056)		0.13 (0.01)		0.115 (0.02)	
	gender x inatt	−0.044 (0.575)		−0.101 (0.21)		−0.098 (0.217)	
	gender x hyp	−0.093 (0.392)		−0.028 (0.807)		0.025 (0.822)	
	gender x imp	0.04 (0.559)		−0.02 (0.778)		−0.075 (0.281)	
	inatt x hyp	0.133 (0.044)		0.157 (0.022)		0.108 (0.111)	
	inatt x imp	0.074 (0.226)		0.028 (0.656)		0.095 (0.126)	
	hyp x imp	−0.114 (0.061)		−0.092 (0.145)		−0.075 (0.229)	

* significant after FDR correction.

3.4. Gender Differences in Additional Support

A total of 334 of the 3020 parents indicated that their child received additional support from a teacher or (special education) therapist. Table 5 shows the numbers of children with ADHD symptoms only, specific learning disorders only, both or none, separately for girls and boys.

Table 5. Numbers and Percentages of Children Receiving Additional Support According to Their Parents.

	Support (*n*)	**Support (%)**	**No Support (*n*)**	**No Support (%)**
ADHD only, boys	12	13	80	87
ADHD only, girls	6	17	29	83
ADHD only, total	18	14	109	86
SLD only, boys	86	21	327	79
SLD only, girls	65	17	312	83
SLD only, total	151	19	639	81
ADHD + SLD, boys	25	28	63	72
ADHD + SLD, girls	21	36	38	64
ADHD + SLD, total	46	31	101	69
No ADHD or SLD, boys	54	6	927	94
No ADHD or SLD, girls	64	7	908	93
No ADHD or SLD, total	118	6	1835	94

ADHD = symptoms of ADHD; SLD = specific learning disorders.

Among children with both ADHD symptoms and specific learning disorders, no difference was found between girls and boys in the additional support they received (OR = 0.72, 95%-CI = 0.33–1.55, $p = 0.37$). Children with comorbid ADHD symptoms and specific learning disorders more often received support than children with specific learning disorders only (OR = 0.52, 95%-CI = 0.35–0.79, $p = 0.001$) or ADHD symptoms only (OR = 0.36, 95%-CI = 0.19–0.69, $p < 0.001$).

4. Discussion

The present study addressed gender differences in learning disorders in reading, spelling and math in a large population-based sample. Regarding our first research question, as expected, girls with ADHD symptoms showed higher rates of learning disorders in reading, spelling and math than girls without ADHD symptoms. Regarding our second research question, we hypothesized that girls with ADHD symptoms would have higher rates of learning disorders in reading, spelling and math than boys with ADHD symptoms. However, this was only the case for learning disorders in math where girls with ADHD symptoms (41.5%) were almost twice as likely to meet the cut-off compared to boys with ADHD symptoms (22.8%). These rates are in line with those reported on in other studies. For example, Silva and colleagues (2020) found that 23% of boys and 28% of girls with ADHD symptoms had numeracy scores below the benchmark in grade 3. In our sample, girls without ADHD symptoms also had a higher rate of math disorders (16.6%) than boys without ADHD symptoms (11.8%), which is in line with previous studies [30]. However, the probability of having learning disorders in math is approximately twice as high for boys who have ADHD symptoms (22.8% vs. 11.8%) but 2.5-fold for girls with ADHD symptoms compared to girls without ADHD symptoms (41.5% vs. 16.6%). We were not able to confirm our hypothesis regarding reading and spelling disorders. The rates of reading disorders and spelling disorders were almost the same in boys with ADHD symptoms and girls with ADHD symptoms. In the general population as well as in our sample, girls showed below-average reading and spelling skills less often than boys. The effects of gender on reading and spelling disorders (girls being less affected) and ADHD symptoms on reading and spelling disorders (children with ADHD symptoms being more affected) might have canceled each other out in girls with ADHD symptoms in our sample, although in other studies higher impairments in reading and spelling have been found in girls with ADHD symptoms [37].

Specific learning disorders are more strongly associated with symptoms of inattention than with symptoms of hyperactivity or impulsivity [38,54]. Girls with ADHD are more often diagnosed with the inattentive subtype of ADHD [16]. In contrast with boys with ADHD, inattention is more pronounced in girls with ADHD, whereas hyperactivity and impulsivity are less pronounced [16]. However, it is not clear whether girls with ADHD have more difficulties because of their gender or because of the peculiarity of their ADHD symptoms. Therefore, our third research question addressed whether gender differences in the probability of developing specific learning disorders in reading, spelling and/or math were due to gender or due to differences in the severity of symptoms of inattention, hyperactivity and impulsivity. Since we found gender differences in math only, the most important finding to address this question is the prediction of math performance by gender and ADHD symptoms. The results indicate that both gender and inattention are significant predictors. Therefore, the differences in math performance cannot be explained solely by heightened inattention in girls with ADHD. When predicting reading and spelling performance gender differences vanished when inattention was considered. Even though in other studies higher rates of reading and spelling disorders were found in girls with ADHD than in boys with ADHD [37], those analyses did not control for inattention.

Our fourth research question addressed the question of whether girls with ADHD symptoms and specific learning disorders received less additional support from a teacher or (special education) therapist than boys with ADHD symptoms and specific learning disorders. Analyses regarding this research question were exploratory and somehow superficial because extracurricular support was assessed with only one item on the parental questionnaire. Since girls with ADHD symptoms are often overlooked in the classroom due to their less disruptive behavior [15], we assumed that girls with ADHD symptoms and specific learning disorders might receive less additional support. However, significant differences in the amount of additional support received by girls and boys with ADHD symptoms and specific learning disorders could not be found. Girls with ADHD symptoms and specific learning disorders seemed to receive even more support (36%) than boys with

ADHD symptoms and specific learning disorders (28%). This difference was not significant though, which might be the result of a power problem. Even though our sample is quite large, the numbers for this analysis are quite small comparing 21 girls to 25 boys. Due to the small number, we refrained from analyzing reading, spelling and math disorders separately. Even though these results should be replicated in a more in-depth assessment of additional support, one might draw the quite promising conclusion that girls with ADHD symptoms and specific learning disorders do not seem to be overlooked regarding extracurricular support in Germany.

4.1. Limitations and Directions for Future Research

Some limitations to the present study need to be mentioned. Even though the sample was meant to be representative of the German population, children of mothers with a high level of educational, which might indicate a high SES, were overrepresented. Since children with ADHD and higher SES often show less impairment [55], our study might underestimate true effects.

We mentioned referral bias as a possible explanation for different results regarding gender differences in clinical and population-based samples. In population-based samples, girls with ADHD symptoms show less impairment than boys with ADHD symptoms; among clinic-referred populations, girls and boys with ADHD show similar levels of impairment [14,15]. In our study girls with ADHD symptoms showed greater comorbid math disorders, which strengthens the argument that girls with ADHD symptoms, regardless of a clinical diagnosis are more impaired in their math performance. We do not know how many of the girls and boys we classified as having ADHD symptoms had already received a clinical diagnosis. Thus, we cannot determine whether girls were really overlooked. Future research should try to disentangle gender effects of ADHD symptoms in population-based samples in which reliable information about clinical diagnoses is available.

We did not use gender-specific norms for grouping the children, but rather a general cut-off percentile of $\geq$90/z-score $\geq$1.28 to classify children as having ADHD symptoms. Gender-specific norms are commonly used in questionnaires designed to assess ADHD (e.g., FBB-ADHS [50]) and in related research (see [56,57] for a discussion). However, using gender-specific norms might contribute to an underestimation of the effect of gender. Therefore, we used general norms as a more conservative test for our hypotheses.

All the tests we used were web-based and not in their original paper-pencil format, and thus, we were unable to observe test administration. We excluded unreliable data as far as possible (e.g., when patterns suggesting unreliability) based on plausibility checks. The online format allowed us to reach a large sample with an extensive test battery and to assess problems in reading, spelling and math in children with ADHD symptoms in a sample large enough to explore gender differences.

Lastly, our study is merely descriptive. We did not focus on causes of gender-specific associations between ADHD symptoms and learning disorders in reading, spelling and math. To determine effective ways to prevent children from developing learning disorders future studies should focus on the factors moderating gender-specific associations between ADHD symptoms and learning disorders (e.g., other dominant language or psychological problems of the parents).

4.2. Implications for Practice

Our results highlight the importance of exploring the comorbidity of learning disorders in children with ADHD symptoms and especially math disorders in girls with ADHD symptoms. Clinicians and teachers should be made aware of gender-specific comorbidities. Girls with ADHD should be screened for math disorders to start interventions early. When planning learning interventions for children with ADHD, the challenges children with ADHD face such as focusing on the task at hand should be considered.

The number of children that received additional support when having ADHD symptoms only (14%) or one or more learning disorders (19%) only was quite low. Even though additional support was assessed with one mere item on a questionnaire, this highlights the importance of addressing all ADHD and learning difficulty symptoms and providing adequate support.

5. Conclusions

The results of this study of a population-based sample confirm that girls with ADHD symptoms exhibit greater comorbid math disorders, but not comorbid reading or spelling disorders, than boys with ADHD symptoms. Math achievement was predicted by gender and by symptoms of inattention. Girls with ADHD symptoms and comorbid math disorders received the same amount of additional support from teachers or therapists as boys with ADHD symptoms and comorbid math disorders. Our results highlight the importance of exploring comorbid specific learning disorders in children with ADHD symptoms and especially math disorders in girls with ADHD symptoms to provide children suitable interventions and prevent accumulation of academic problems.

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Data Availability Statement: The data presented in this study and the syntax for the analysis are openly available at the Open Science Framework at https://osf.io/bw5cm/ (accessed on 14 July 2021).

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Descriptive statistics on SES in the sample.

Table A1. Contingency Table of SES and ADHD Symptoms.

	ADHD		
Characteristic	**No Problems**	**Indication of Problems**	**Total**
Highest level of education of mother			
No degree (kein Abschluss)	34 (1.2%)	9 (3.3%)	43 (1.4%)
Secondary school (Hauptschulabschluss)	181 (6.6%)	20 (7.3%)	201 (6.7%)
Secondary school (Mittlere Reife)	600 (22%)	83 (30%)	683 (23%)
University entrance degree (Fachabitur)	313 (11%)	41 (15%)	354 (12%)
University entrance degree (Allgemeine Hochschulreife)	1618 (59%)	121 (44%)	1739 (58%)
Total	2746 (100%)	274 (100%)	3020 (100%)

ADHD = symptoms of ADHD.

Significant differences were found between the groups: X (4, N = 3020) = 27.5, $p < 0.01$ (2-tailed). The standardized residuals appear to be > 2 for “no degree”, “general secondary school degree” and “university entrance secondary school degree”.

Table A2. Standardized Residuals for Level of Mother's Education for Children with or without ADHD Symptoms.

	No Problems	Indication of Problems
No degree (kein Abschluss)	−2.73	2.73
Secondary school (Hauptschulabschluss)	−0.45	0.45
Secondary school (Mittlere Reife)	−3.19	3.19
University entrance degree (Fachabitur)	−1.75	1.75
University entrance degree (Allgemeine Hochschulreife)	4.71	−4.71

Conclusion: The mothers of children with severe ADHD symptoms tended to have "no degree" or a "general secondary school degree" and less often "university entrance secondary school degree" as their highest level of education.

Table A3. Contingency Table of SES and Learning disorders (Based on Cut-Off of 1 SD).

	Learning Disorders Using Cut-Off-1sd (No/Yes)		
Characteristic	**No Problems**	**Indication of Problems**	**Unknown**
Highest level of education of mother			
No degree (kein Abschluss)	22 (1.1%)	21 (2.2%)	0 (0%)
Secondary school (Hauptschulabschluss)	97 (4.7%)	103 (11%)	1 (33%)
Secondary school (Mittlere Reife)	428 (21%)	255 (27%)	0 (0%)
University entrance degree (Fachabitur)	224 (11%)	129 (14%)	1 (33%)
University entrance degree (Allgemeine Hochschulreife)	1309 (63%)	429 (46%)	1 (33%)

Significant differences were found between the groups: X (4, N = 3017) = 95.89, $p < 0.01$ (2-tailed). The standardized residuals appear to be >2 for all SES categories.

Table A4. Standardized Residuals for Level of Mother's Education for Children with or without Learning Disorders.

	No Problems	Indication of Problems
No degree (kein Abschluss)	−2.54	2.54
Secondary school (Hauptschulabschluss)	−6.47	6.47
Secondary school (Mittlere Reife)	−4.03	4.03
University entrance degree (Fachabitur)	−2.37	2.37
University entrance degree (Allgemeine Hochschulreife)	8.82	−8.82

Mothers of children with a learning difficulty tended to have a low or average level of education and less often a high level of education.

Appendix B

Measurement invariance of the FBB-ADHS in relation to gender.

We ran a multiple-group confirmatory factor analysis (MG-CFA) in R using the lavaan-package [58] based on a model in which scores for the three ADHD subtypes (inattention, hyperactivity, impulsivity) were indicators of ADHD. The results, which are shown in

Table A2.1 indicate strong invariance in relation to gender (equal loadings and intercepts) but not strict invariance (equal residuals).

Table A5. Results of the Multiple-Group Confirmatory Factor Analysis.

	AIC	BIC	χ2	df	χ2 Difftest	*p*	RMSEA	CFI	ΔCFI
Configural inv.	11560	11668	0.000	0			0.000	1.000	
Loadings	11568	11664	11.970	2	11.970	<0.01	0.057	0.996	0.004
Intercepts	11580	11665	28.484	4	16.514	<0.001	0.064	0.991	0.005
Residuals	11622	11688	75.474	7	46.990	<0.001	0.080	0.975	0.016

Inv. = invariance; criteria: CFI ≥ 0.95; RMSEA ≤ 0.08; ΔCFI ≤ |0.01|.

Appendix C

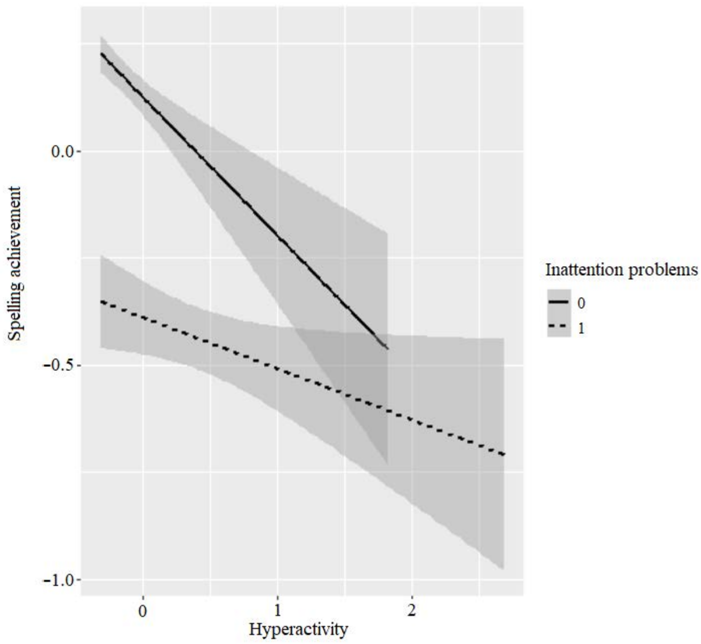

Figure A1. Interaction of inattention and hyperactivity in predicting spelling achievement.

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