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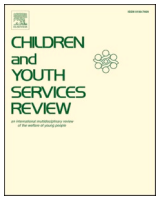

Associations of inattention, hyperactivity, and sex with behavioral–emotional symptoms among children with mathematical disability

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ABSTRACT

Objective: We studied the association between inattention and hyperactivity symptoms and other behavioral–emotional symptoms among children with mathematical disability after controlling for severity of the mathematical disability and comorbid reading disability. We also analyzed the effects of sex.
Method: Participants were 362 Finnish elementary school children (M_{age} = 10.25; SD_{age} = 1.08) who attended a clinic which specialized in assessment of learning disabilities. Inattention, hyperactivity, and other behavioral–emotional symptoms were assessed with teacher ratings (TRF/ASEBA). Mathematics and reading were assessed as part of the clinical assessment with grade-normed tests. The mathematical disability was identified during the assessment process. Hierarchical regression analyses were used to analyze the associations.
Results: The percentages of children showing behavioral–emotional problems were high varying between 10 and 42% depending on the problem scale and sex. Problems of inattention and hyperactivity were also common, and the direct contributions of inattention to internalizing symptoms (explaining 2–20% of the variability) and of hyperactivity to externalizing symptoms (explaining 20–22% of the variability) were substantial. Mathematical disability severity and comorbid reading disability had minimal contribution, and inattention and hyperactivity partially negated these contributions. Inattention and hyperactivity had additional contributions to internalizing and externalizing symptoms moderated by sex. Inattention increased somatic (7%), affective (22%), and conduct symptoms (4%) only among boys. Hyperactivity increased oppositional defiant symptoms (21%), especially among boys.
Conclusions: The results underline the importance of addressing behavioral–emotional problems among children with mathematical disability. As inattention symptoms and hyperactivity symptoms contribute to the occurrence of other behavioral–emotional symptoms, they should be considered in the assessment process and support planning of children with mathematical disability. Longitudinal design is needed to understand how especially inattention contributes to the formation of behavioral–emotional symptoms among children with mathematical disability.

1. Introduction

Educators' and researchers' concerns about children's psychological well-being related to mathematics have increased as practicing mathematics, or having difficulties in learning mathematics, have been reported to be related to strong emotions (Towers et al., 2018), poor motivation in adolescents (Parhiala et al., 2018), and mathematics-related anxiety (Sorvo et al., 2022; Wu et al., 2014). Of concern, mathematics-related anxiety has been found already in the early years of schooling (Sorvo et al., 2017). As most of the research on behavioral–emotional symptoms has, thus far, focused in either children with unspecified learning disability (e.g., Nelson & Harwood, 2011a; 2011b)

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or children with reading disabilities or poor reading (e.g., Francis et al., 2019), little is yet known about behavioral–emotional problems among children meeting criteria for mathematical disability (MD). However, the few existing studies have shown that both internalizing (i.e., inner-directed problems, like anxiety and depression, causing internal psychological distress) and externalizing (i.e., outer-directed problems, like conduct problems and oppositionality, bothering others and causing interpersonal conflicts) symptoms are worryingly common among children with MD (Auerbach et al., 2008; Graefen et al., 2015; Wakeman et al., 2023; Willcutt et al., 2013). Moreover, because MD is known to be common (3–7 %; American Psychiatric Association., 2013) and even higher percentage of individuals lack basic numerical knowledge (e.g., Snyder & Dillow, 2012), studies on the possible mechanisms related to the co-occurrence of behavioral–emotional symptoms and MD are needed as they have implications for special educational support.

1.1. Evidence of behavioral–emotional symptoms among children with MD

It is well-known that childhood behavioral–emotional problems alone are linked with failures in achieving educational and social milestones (National Research Council and Institute of Medicine [NRC and IoM], 2009; Reid et al., 2004), and that co-occurring learning and behavior problems increase the risk of poor educational attainment (Smart et al., 2017). Additionally, based on longitudinal studies, we know that childhood learning disability is associated with adverse outcomes in education, employment, and psychological well-being in adulthood (Eloranta et al., 2019; McLaughlin et al., 2014), and especially childhood MD has been found to be associated with later antidepressant use and unemployment (Aro et al., 2019). It has also been shown that psychiatric problems in adolescence mediate between learning disability and adult-age psychiatric diagnoses, and that among individuals with MD, childhood internalizing and/or externalizing problems followed by psychiatric diagnoses in adolescence predict anxiety in adulthood (Eloranta et al., 2021).

Among school-aged children with MD, both internalizing and externalizing behavioral problems have been found, but the studies are few and the findings have not been consistent. Internalizing problems, such as anxiety and depression (Wakeman et al., 2023; Willcutt et al., 2013), eating disorders, and somatization (Graefen et al., 2015), and externalizing problems, such as oppositional defiant and conduct problems (Auerbach et al., 2008; Willcutt et al., 2013; Wakeman et al., 2023), have been reported among children meeting the criterion set for MD in each study. However, Wu et al. (2014) did not find an association between mathematics achievement and internalizing symptoms in their nonclinical sample. Despite the inconsistency, children with MD seem to be in an elevated risk of having behavioral–emotional symptoms already in elementary school, and this co-occurrence should be taken seriously both by researchers and educators. However, little is known about the child-related characteristics that may contribute to this co-occurrence, but, as indicated below, ADHD symptoms seem to be associated with the occurrence of behavioral-emotional problems among children with learning difficulties/disabilities.

1.2. ADHD as a factor explaining behavioral–emotional symptoms in children with MD

Cumulating evidence suggests that comorbid ADHD influences other behavioral–emotional symptoms in children with learning difficulties/disabilities. Among children with RD, internalizing symptoms of somatic problems, anxiety, and depression (Arnold et al., 2005; Carroll et al., 2005; Goldston et al., 2007; Willcutt & Pennington, 2000; Willcutt et al., 2013) and externalizing symptoms of oppositional defiant disorder and conduct problems have been found to be related to ADHD symptoms (Carroll et al., 2005; Willcutt et al., 2013). Despite equivocality, the findings on RD propose that the effect of ADHD is more prominent on externalizing than on internalizing symptoms.

Some results have also been reported among those with MD, but the findings are somewhat ambiguous. Willcutt et al. (2013) reported that the link between MD and externalizing disorders (oppositional defiant and conduct problems) was restricted to children with comorbid ADHD. They also found that children with MD and ADHD exhibited higher rates of anxiety than those without ADHD, but children with MD or with both MD and RD had higher rates of depression than the controls, irrespective of ADHD. Contrary results have been reported by Visser et al. (2020). In their population-based sample, mathematics achievement predicted anxiety after ADHD was considered. They also detected a moderating effect of ADHD symptoms on the relationship between depression and mathematics.

Although the association between RD and MD and behavioral–emotional problems has been shown (Graefen et al., 2015; Auerbach et al., 2008; Wakeman et al., 2023; Willcutt et al., 2013), and there is evidence that ADHD symptoms contribute to this association among those with RD (Arnold et al., 2005; Carroll et al., 2005; Goldston et al., 2007; Willcutt & Pennington, 2000; Willcutt et al., 2013), the evidence for those with MD is scarce (Willcutt et al., 2013), and the mechanisms behind these associations are not known. It can be supposed that the mechanisms linking ADHD symptoms, behavioral–emotional problems, and MD lie in the self-regulative functions related to them. Both ADHD (e.g., Roberts et al., 2017) and MD (e.g., Mazzocco & Kover, 2007) have been shown to be directly linked with deficient executive functions, and ADHD has additionally been shown to relate to emotion regulation difficulties (e.g., Astenvald et al., 2022: Steinberg & Drabick, 2015) suggesting a link also between emotion regulation difficulties and deficits in self-regulation. This is in accordance with the views in which self-regulation is understood as a broader construct within which emotion regulation and executive functioning/effortful control are included (see Gagne et al., 2021).

Furthermore, good executive functions and effective emotion regulation have been shown to be associated with improved school achievement (Diamond, 2013; Gumora & Arsenio, 2002) and psychological well-being (Halse et al., 2022; Karalunas et al., 2022; Schafer et al., 2017). It has been suggested that these association are due to their paramount importance for self-regulative functions as emotion regulation provides an affective form of self-regulation and executive functions provide a cognitive one (Blair & Ku, 2022). Sufficient executive functions enable self-regulation through higher functions, such as planning, adapting, and evaluation (Nigg, 2017), which are all needed in efficient school learning. Thereby, it can be theorized that deficits in executive functions related to both ADHD symptoms and MD are also associated with the behavioural–emotional symptoms among those with MD. Similarly, emotion regulation difficulties related to ADHD may hamper coping with MD and thereby escalate behavioral–emotional symptoms.

Analyzing the theoretical possibilities was out of the scope of the present study, but instead, we aimed at better understanding of the contribution of teacher-reported ADHD symptoms (inattention and hyperactivity) to the occurrence of different types of internalizing and externalizing symptoms among children with MD as previous research has mainly targeted RD. Thus, we examined whether inattention and hyperactivity had contribution on the amount of behavioral–emotional symptoms and whether these associations were moderated by sex. Better understanding of these factors would guide future intervention development and theory building.

1.3. Distinctive effects of inattention and hyperactivity

Studies analyzing ADHD and behavioral–emotional symptoms among children with learning difficulties or disabilities have mainly considered ADHD as a categorical variable by grouping children as having or not having ADHD (Arnold et al., 2005; Goldston et al., 2007; Willcutt et al., 2013). This is rather surprising, since the nominal subtypes of ADHD have been found to be relatively unstable over time, and

thus, the use of a dimensional approach reflecting the number of inattention and hyperactivity-impulsivity symptoms has been proposed (e.g., Larsson et al., 2012). This approach is also supported by research indicating that children demonstrating symptoms of ADHD without a formal diagnosis have an elevated risk of difficulties in academic skills (e.g., Loe & Feldman, 2007), which suggests that subclinical levels of these symptoms should also be considered.

Hyperactivity and inattention have been reported to be differentially associated with behavioral–emotional symptoms (e.g., Power et al., 2004). A recent study on reciprocal and temporal relations between ADHD symptoms and emotional problems among school-age children suggested that increased inattention symptoms may play a prominent role in the bidirectionality and persistence of emotional problems (Han et al., 2020). Similar effects were not found when only hyperactivity/impulsivity symptoms and emotional problems were considered. These finding suggest for a differential association between ADHD symptom domains and behavioral-emotional problems. Similarly, hyperactivity and inattention have also been shown to be differentially associated academic problems suggesting a greater significance for the inattentive component of ADHD (Lamminmäki et al., 1995; Tosto et al., 2015; Wakeman et al., 2023). However, only a few studies on learning difficulties or disabilities have considered inattention and hyperactivity/impulsivity separately.

As the existing evidence comes from studies among children with RD, we lack knowledge of the possible differential associations of hyperactivity and inattention with behavioral–emotional symptoms among children with MD. Studies concerning children with reading difficulties have mostly reported evidence regarding the effects of inattention, but the findings depend on which behavioral–emotional symptoms are studied (Carroll et al., 2005; Maughan et al., 2003). Concerning mathematics, Visser et al. (2020) reported that inattention fully accounted for the relationship between mathematics and conduct disorders in their population-based sample; that is, academic achievement did not have an effect after adding ADHD into the analysis. Further analyses revealed that the effect was caused by inattention symptoms; mathematics remained significant predictor after considering hyperactivity.

In sum, although the previous findings are inconclusive and mostly based on RD, it can be surmised – with caution – that especially inattention may account for the relationship between academic deficit and conduct problems (Maughan et al., 2003; Visser et al., 2020), whereas the effect of academic deficit might have a more direct association with anxiety (Carroll et al., 2015). However, the effects of hyperactivity are seldom reported and are poorly known. Despite the ambiguity, the findings underlie the importance of considering inattention and hyperactivity separately and analyzing behavioral–emotional symptoms independently instead of in clusters of internalizing and externalizing behavior as has commonly been done. Separate analyses may provide new understanding on the mechanisms underlying the comorbidity between MD and diverse other behavioral–emotional symptoms and on the role of inattention and hyperactivity.

1.4. Effects of sex

There is clear evidence of sex effects on behavioral–emotional symptoms. Girls are more prone to somatic disorders, depression, and anxiety, whereas boys are more prone to have oppositional defiant and conduct disorders and ADHD (Altemus et al., 2014; Martel, 2013). The findings on sex-related differences on behavioral–emotional symptoms among children with learning difficulties are not as consistent, and many studies have not reported sex differences (e.g., Nelson & Harwood, 2011a, 2011b). Some studies have found higher levels of depressive symptoms among girls with learning difficulties (Heath & Ross, 2000; Martínez & Semrud-Clikeman, 2004), but contrary findings have also been reported among children with literacy difficulties (Carroll et al., 2005).

Consequently, little is also known about sex-related effects on behavioral–emotional symptoms among children with MD. However, Graeffen et al. (2015) reported that boys with MD received high ratings on internalizing problem scales. They also reported differences in the types of internalizing problems demonstrated by boys and girls; boys with MD showed more somatization than boys without MD, while girls with MD reported more symptoms of depression than did the girls in the control group. Wu et al. (2014) found that the relationship between mathematics achievement and externalizing problems was stronger in girls than in boys as rule breaking and aggression were negatively correlated with achievement among girls. Recently, Wakeman et al. (2023) reported generally similar associations between mathematics and behavioral–emotional symptoms in boys and girl. Due to a lack of research and differing findings, more knowledge is needed on possible sex-related differences among children with MD.

Sex-related differences have also been detected in the behavioral–emotional symptoms of individuals with ADHD (Ottosen et al., 2019). For instance, oppositional defiant (ODD) and conduct disorder (CD) have been found to be common among males with ADHD (Biederman et al., 2008), whereas anxiety, distress, and depression have been found to be more common among females with ADHD (Rucklidge & Tannock, 2001). There are indications that inattention and hyperactivity-impulsivity may have differential relationships to other behavioral–emotional symptoms among boys and girls. Bauermeister et al. (2007) found that boys with both inattention and hyperactivity-impulsivity symptoms (ADHD combined subtype) were more likely to show mood disorders than girls, and inattentive girls were more likely to have anxiety disorders than boys with inattention. However, we do not know whether sex has a moderating effect on behavioral–emotional symptoms via inattention or hyperactivity among children with MD. Thus, we studied in the present study whether sex has a direct effect on behavioral–emotional symptoms among children with MD or whether it moderated the associations between inattention / hyperactivity and other behavioral–emotional symptoms.

1.5. The current study

This study builds on our recent study (Aro et al., 2022) that reported high percentages of children demonstrating behavioral–emotional problems in three subgroups of children with learning disabilities: those with only reading disability (RD-only), only mathematical disability (MD-only), or those with comorbid MD and RD. Despite only a few differences emerged between the subgroups, the findings raised concern for children with MD-only, as the highest percentages of children with clinically relevant behavioral–emotional problems were detected among them. In the present study, we used the same data to analyze the contribution of inattention and hyperactivity to the amount of teacher-rated behavioral–emotional symptoms among children with MD.

Before analyzing the effects of inattention and hyperactivity, we controlled for the effect of the grade-level normed score of mathematics achievement (i.e., severity of MD) and of comorbid RD. It has been speculated that children with low mathematics achievement and those with MD differ (Wakeman et al., 2022; Wu et al., 2014). Comorbidity of MD with RD, in turn, is known to be common (Joyner & Wagner, 2020), and RD also often co-occurs with behavioral–emotional symptoms (e.g., Francis et al., 2019; Livingston et al., 2018). However, the existing knowledge on the effect of comorbid RD on behavioral–emotional symptoms among children with MD is equivocal. Willcutt et al. (2013) found that the combination of RD and MD may have a coactive effect, increasing the probability of internalizing symptoms. However, Wakeman et al., (2023) found that children with problems in mathematics had elevations in several behavioral–emotional symptoms, and the main effect of MD remained significant for internalizing problems after controlling for reading.

We first report what percentage of children with MD or with MD and

comorbid RD demonstrated teacher-rated behavioral–emotional problems (i.e., amount of symptoms above the cut-off of 1.5 SDs), and then examined the association of these problems and inattention and hyperactivity, and the effect of sex on these associations. The specific research questions addressed in the present study were the following:

(1) To what extent inattention or hyperactivity had unique explanatory power on behavioral–emotional symptoms after controlling for the severity of MD and comorbid RD?

(2) Did sex have a direct effect on behavioral–emotional symptoms or did it moderate the possible effects inattention or hyperactivity on behavioral emotional symptoms?

2. Methods

2.1. Procedure and participants

The sample was derived from the clinical database of the Clinic for Learning Disorders (CLD), which has offered assessment and intervention services for children with learning disabilities (typically 7–13 years of age), referred by the local Family Counseling Center or school psychologists, since 1985. CLD is a public clinic. The services are free for families and CLD does not provide other services (e.g., healthcare, or social services), thus, it does not pose the families in an advantageous position by providing services not related to learning. There are no formal exclusionary criteria, but children with behavioral–emotional symptoms, as their *primary* problems, are not referred to the CLD. Parents gave informed consent to use the data for research, and the institutional consent to use the data was provided by Niilo Mäki Institute, and the Ethics Committee of the University of Jyväskylä had given its approval for the study. The study was not preregistered.

Before referring the child to CLD, the learning difficulties were noticed by classroom teachers or parents and assessed by special education teachers. Commonly, individually planned and/or intensified educational support has also been provided. It should be noted that a special education teacher with master's degree is available in every school and no formal diagnosis is needed for special educational support in Finland. If learning difficulties persist despite the intensified support provided, the school psychologist or a decision-making team is involved in the assessment and support planning (Björn et al., 2016). The team comprises administrators, teachers, school psychologists, and parents. This multi-tiered framework with systematized assessment and instruction, cyclic support, and modifiable instruction closely resembles the Response to Intervention model (e.g., Fletcher & Vaughn, 2009).

At the CLD, a comprehensive assessment comprising neuropsychological tests, reading and mathematics tests, and parental and teacher questionnaires on behavioral–emotional symptoms is conducted. The tests have varied over the years (1985–2017); therefore, the assessment of MD and definition of RD were based on the test used at the time the child attended the clinic. Clinical judgment was used in choosing relevant measures at the CLD, and some children had missing data for some measures.

For the purposes of the present study, we selected children with age and/or grade, sex, and both reading and mathematics scores available. Furthermore, we selected only children who clearly demonstrated MD; that is, their performance was at least 1.5 SDs below the mean of the reference group in the mathematics test conducted at the CLD. In previous studies, identification of individuals with learning disabilities has varied and there is no consensus on the cut-off, and thus, several different cut-offs have been used. For instance, performance 1.25 (e.g., Willcutt et al., 2013) or 2.0 SDs (Heiervang et al., 2001) below age- or grade-level, or belonging to the lowest 5th (e.g., Auerbach et al., 2008), 10th (e.g., Graefen et al., 2015), or 18th (e.g., Arnold et al., 2005) percentile, have been used. In the present study, the cut-off of −1.5 SDs was chosen as it corresponds to 7th percentile in normal distribution, and it is in line with previous studies on learning disabilities being at the lower end of the cut-offs previously used, thus, not being too lenient. The same cut-off was used for behavioral–emotional problems. To define whether the child demonstrated MD or RD the national or local Finnish norms for each grade level were used (*note*: no national norms were available for all tests). To define whether the child demonstrated a clinically relevant amount of behavioral–emotional symptoms, we used a cut-off $\geq$1.5 SDs above the mean of the Finnish normative sample. This corresponds well to the commonly used cut-off T-score $\geq$ 65 in the ASEBA syndrome scales. However, a T-score $\geq$ 69 is suggested for *DSM*-oriented scales (Achenbach & Rescorla, 2001, p. 92).

There were 1,234 children's data in the database, and 830 of them had both reading and mathematics scores available, and 422 met the criteria for MD. IQ scores were not used when defining MD, but we excluded children with both verbal and performance IQs below 75. Verbal and performance IQ scores from the Finnish versions of the WISC-R (Wechsler, 1974), WISC-III (Wechsler, 1991), the Verbal Comprehension Index, and the Perceptual Reasoning Index from the WISC-IV (Wechsler, 2003) were used. Twelve children had IQ scores below 75, and 48 had missing IQ scores or teacher ratings on behavioral–emotional symptoms. They were excluded from the analysis. This procedure yielded a final sample of 362 children with MD: 227 (62.70 %) boys and 135 (37.30 %) girls. The mean age was 10.25 years ($SD = 1.08$; grade $MED = 4$; IQ $M = 87.76$, $SD = 10.59$). Of the 362 children, 231 had comorbid RD. Mother's educational degree was used as a proxy of socioeconomic status. Using our categories (1 = comprehensive school or unspecified; 2 = high school/vocational school; 3 = polytechnic, college; 4 = university degree, i.e., master or higher) median educational level was being high school/vocational school (min = 1; max = 5; $M = 1.90$; $SD = 1.02$).

2.2. Measures

2.2.1. Measures of mathematics achievement and definition of MD

The MD definition was based on the mathematics test the child had completed during the assessment at the CLD. The criterion of MD was a performance that was below or at −1.5 SD compared to the norms of the test used. One of the following three tests assessing mathematics achievement with items tapping into arithmetic skill had been used in the assessment processes of the children in this sample: K-ABC, RMAT, or Lukilasse. Different tests had been used because the tests used at the CLD had changed over the years. The test had local or national norms and norming was based on number of correctly answered items. The Kaufman Assessment Battery for Children (K-ABC; Kaufman & Kaufman, 1983) includes 38 items tapping into knowledge of numbers, mathematical semantical concepts, and computational skills. The internal consistency values of the K-ABC have been found to be at least 0.86 among school-aged children. Local Finnish norms are available for grades 2–5 (NMI, 1985–2004). In the RMAT (Räsänen, 1992; normed for grades 3–6), the child is requested to perform as many basic arithmetical operations as possible in 10 min. The test has high internal validity and reliability (Cronbach alpha.86) and test–retest reliability ($r = 0.82$, 6 months interval and $r = 0.76$, 14 months). The mathematics subtest of the Lukilasse (Häyrinen et al., 1999) consists of basic arithmetic operations normed for grades 1–6. Cronbach's alpha of the test ranged between 0.55 and 0.83 depending on the grade (Häyrinen et al., 1999). The child's grade-level normed score in the mathematics achievement test which he or she had completed during the assessment process was used to control for the effects of MD severity.

2.2.2. Definition of comorbid RD

The definition of comorbid RD was based on child's reading in one of the text- or wordlist-reading tests used at the CLD (for more details, see Aro et al., 2022): the Misku-Text, the Ärps, the Markkinat Word List (NMI, 1985–2004), or the Lukilasse (Häyrinen et al., 1999). The tests had local or national norms collected at the time they were used at the CLD. If the grade-level standardized score was $\leq$ -1.5 SDs, the children were designated as having RD. Thus, the children identified as having MD without comorbid RD had to have a mathematics score $\leq$ -1.5 SD

and a reading score above −1.5 SD. In the case where the child had both scores ≤ -1.5 SD, she/he was identified as having MD and comorbid RD.

2.2.3. Measures of behavioral–emotional problems

Symptoms of inattention and hyperactivity as well as other behavioral–emotional symptoms were rated by teachers using Teacher Rating Forms (TRF) from the Achenbach System of Empirically Based Assessment (ASEBA; Achenbach & Rescorla, 2001) as it provides separate scores for inattention and hyperactivity, which cannot be counted based on the parental questionnaire. We used six DSM-oriented scales consistent with particular DSM-IV diagnostic categories (Achenbach & Rescorla, 2001). They have been reported to have validity for both clinical and non-clinical populations (Achenbach & Rescorla, 2001, p. 114). The Cronbach's alphas of the TRF DSM-oriented scales have been reported to vary between 0.73–.90 (Achenbach & Rescorla, 2001, p. 101). The alphas varied between 0.64–.93, and 0.62–.94 in our clinical and normative data, respectively.

A population-based Finnish normative sample was used to calculate the standardized scores for the current sample. The regional school-based normative sample comprised 1,695 children (834 boys and 861 girls; aged 6 to 16 years). The response rate was 77 %, and the referred children were not excluded (Rescorla et al., 2007). As the clinical data used in this study have been gathered since 1985, the versions of the TRF have changed over the years. Therefore, the few items that differed in the questionnaire versions were excluded, and the scales were calculated similarly for both the CLD data and the local normative population-based sample. Of the internalizing scales, affective problems comprised nine items (e.g., cries a lot; feels worthless or inferior), anxiety problems comprised six items (e.g., fears certain animals, situations, etc.; nervous, tense), and somatic problems comprised seven items (e.g., aches, pain, nausea). Of the externalizing scales, oppositional defiant problems comprised five items (e.g., argues a lot; disobedient at home/at school), and conduct problems included 12 items (e.g., destroys property belonging to others; mean, cruel to others). The inattention scale comprised five items (e.g., fails to finish; inattentive), and hyperactivity scale comprised eight items (e.g., can't sit still; fidgets). A cut-off ≥ 1.5 SDs above the mean of the normative sample was used to define behavioral–emotional problem.

2.3. Data analyses

Data preparation included transformations of the right-skewed TRF scale scores. After Box-Cox transformations (Osborne, 2010), all distributions, except somatization, were normal or close to normal and included no outliers. The distribution of mathematics achievement was normal; therefore, no transformation was needed for it. We performed hierarchical linear regression analyses separately for each TRF scale score (affective, anxiety, somatic, oppositional defiant, and conduct problems symptoms) as the dependent variable. This resulted in five separate regression models. The severity of MD (i.e., z-score of the mathematics achievement test) and dichotomous comorbid RD status (0 = No RD, 1 = Comorbid RD) was entered as step 1 to control the possible effects of severity of MD and comorbid RD on amount of behavioral–emotional symptoms. In step 2, separate measures of inattention and hyperactivity were entered to study to what extent they explained variability in behavioral–emotional symptoms (RQ2). The effect of sex (0 = Girl, 1 = Boy) was studied next by entering it into the models in step 3 (RQ3). Finally, the possible moderating effect of sex was studied in step 4 by entering sex x inattention, and sex x hyperactivity interaction terms into the models (RQ3). Additionally, due to skewed distribution in somatization bootstrap option with 1000 samples was used in the hierarchical linear regression analysis related to somatization to assure the reliability of the *p*-values related to the coefficients.

The data were saved digitally until 2017, and the participants of the present study were assessed between 1985 and 2017 as follows: 62 (16.3 %) during 1985–1994, 160 (41.9 %) during 1995–2004, 143 (37.5 %) during 2005–2014, and 17 (4.5 %) during 2015–2017. In the following, we will call these four groups formed based on the year of assessment, subsamples. When preliminary analyzing the severity of MD and behavioral–emotional symptoms in the four subsamples, it was noticed that the severity of MD was higher, and teachers reported fewer conduct problems in the last subsample assessed 2015–2017. Therefore, we conducted additional analyses without the last subsample, and the results reported in the Results section with the whole sample were corroborated with the smaller data except that in somatic symptoms, where step 4 was non-significant ($p = 0.076$) although the interaction term sex x inattention was significant similarly as in the whole sample. In oppositional defiant symptoms, a small but significant sex-effect emerged as boys showed higher amount of symptoms than girls. As the differences between the whole sample, including all subsamples, and the sample without the last subsample were few, we report below the results concerning the whole sample.

3. Results

Descriptive statistics are presented in Table 1. The percentages of children showing clinically relevant amount (i.e., ≥ 1.5 SD) of inattention, hyperactivity, and other internalizing (i.e., affective, anxiety, somatic) and externalizing (i.e., oppositional defiant and conduct problem) symptoms are presented in Table 2. Strikingly, more than two-thirds of the girls and half of the boys had inattention problems, whereas less than 20 % of the girls and one-third of the boys had hyperactivity problem. Also, affective and anxiety problems: problems were common as 41.5 % of the girls and 37.6 % of the boys showed affective problems and in 26.7 % of the girls and 33.6 % of the boys showed anxiety problems.

Hierarchical linear regression analyses separately for internalizing and externalizing scales were used to answer the rest of the research questions (RQ1 and RQ2). Table 3 shows the results of the analyses for internalizing scale scores (affective, anxiety, and somatic symptoms), and Fig. 1 shows the percentages of variance of separate scale scores explained by different predictors. In step 1, severity of MD was associated with an increase only in affective symptoms, whereas comorbid RD was associated with a decrease in both affective and anxiety symptoms, but not in somatic symptoms. In step 2, inattention had a large effect on all scales of internalizing problems explaining 2–20 % of their variability, while hyperactivity was not associated with any of the internalizing symptoms. The increasing effect of inattention was large on affective and somatic symptoms but small on anxiety symptoms.

To study the direct effect of sex or its possible moderating effect on the association between inattention or hyperactivity and internalizing symptoms (RQ2), further two steps were added to the analysis. Step 3 showed that sex had a significant direct effect on all internalizing scale scores. In terms of affective and anxiety symptoms, boys showed more symptoms than girls, whereas girls had more somatic symptoms. Step 4

Table 1
Demographic Information of the Sample and Means and Standard Deviation of Arithmetic Achievement z-Score.

	MD $N = 362$	
Girls/boys	135/227	
	M	SD
Age (years)	10.25	1.08
Grade	3.61	1.09
Verbal IQ/VCI	89.16	11.74
Performance IQ/PRI	88.37	14.62
MD severity (z-score)	−2.67	1.02

Note. Verbal IQ and Performance IQ scores from the Finnish versions of the WISC-R (Wechsler, 1974) and WISC-III (Wechsler, 1991) and the Verbal Comprehension Index (VCI) and the Perceptual Reasoning Index (PRI) from the WISC-IV (Wechsler, 2003) were used.

Table 2
Percentages of Children showing behavioral–emotional problems in MD group.

	MD $N = 362$	
DSM Oriented Scale	Girl	Boy
Internalizing scales		
Affective Problems	41.5	37.6
Anxiety Problems	26.7	33.6
Somatic Problems	12.9	16.0
Externalizing scales		
Inattention Problems	72.6	55.9
Hyperactivity Problems	17.9	33.2
Opp. Defiant Problems	20.7	25.1
Conduct Problems	9.6	19.9

indicated that sex moderated the effect of inattention on affective and somatic symptoms. Inattention was a significant predictor of affective symptoms for both girls and boys, but the portion of variance explained by it was larger in boys (22 % vs. 9 % for boys and girls, respectively). Inattention increased somatic symptoms only in boys.

Table 4 shows the results of the hierarchical linear regression analyses for externalizing scales (oppositional defiant and conduct problems). In step 1, the severity of MD had a significant effect on oppositional defiant symptoms, more severe MD was related to more oppositional defiant symptoms. Step 1 was significant also in predicting conduct problems, but both severity of MD and comorbid RD failed to show a significant effect on it. Inattention and hyperactivity (RQ1) had significant effects on both externalizing scales in step 2. The effect of inattention was small (1–3 %) compared to the portion of variance

Table 3
Results of the regression analyses for the predicting symptoms in the internalizing scales.

	Affective problems			Anxiety problems			Somatic problems		
	R^2 change	β	95 % CI	R^2 change	β	95 % CI	R^2 change	β	95 % CI
Step 1	**0.045*****			**0.034****			**0.004**		
MD severity		−0.079***	−0.123–-0.035		−0.015	−0.031–.001		−0.051	−0.154–.052
Comor. RD		−0.100*	−0.193–-0.007		−0.053**	−0.088–-0.019		−0.074	−0.292–.144
Step 2	**0.162*****			**0.071*****			**0.078*****		
MD severity		−0.058**	−0.098–-0.017		−0.010	−0.025–.006		−0.020	−0.120–.080
Comor. RD		−0.066	−0.151–.019		−0.044**	−0.077–-0.011		−0.023	−0.234–.188
Inattention		0.123***	0.091–.155		0.023***	0.010–.035		0.201***	0.122–.280
Hyperactivity		−0.008	−0.032–.015		0.006	−0.003–.016		−0.024	−0.084–.036
Step 3	**0.014***			**0.018****			**0.042*****		
MD severity		−0.057**	−0.097–-0.017		−0.009	−0.025–.006		−0.022	−0.120–.075
Comor. RD		−0.072	−0.157–.012		−0.047**	−0.080–-0.014		0.009	−0.198–.216
Inattention		0.136***	0.103–.170		0.028***	0.015–.041		0.149***	0.067–.231
Hyperactivity		−0.014	−0.038–.010		0.004	−0.005–.013		0.001	−0.059–.061
Sex		0.115*	0.027–.202		0.047**	0.013–.081		−0.443***	−0.659–-0.227
Step 4	**0.027****			**0.009**			**0.016***		
MD severity		−0.054**	−0.094–-0.015		−0.009	−0.079–.007		−0.017	−0.114–.081
Comor. RD		−0.069	−0.152–.015		−0.046**	−0.079–-0.013		0.012	−0.194–.218
Inattention		0.095***	0.054-0.136		0.023**	0.007–.039		0.074	−0.026–.175
Hyperactivity		−0.009	−0.036–.018		0.002	−0.009–.012		0.018	−0.050–.087
Sex		0.091*	0.046–.261		0.041*	−0.007–.076		−0.476***	−0.693–-0.258
Sex x Inatt.		0.157***	0.062–.251		0.018	−0.019–.055		0.290*	0.058–.522
Sex x Hyp.		−0.016	−0.083–.051		0.012	−0.014–.039		−0.083	−0.249–.083
Total R^2	**0.249; $F(7,352) = 16.648$*****			**0.132; $F(7,351) = 7.641$*****			**0.139; $F(7,341) = 7.888$*****		

* $p < 0.05$, ** $p < 0.01$, ***<.001.

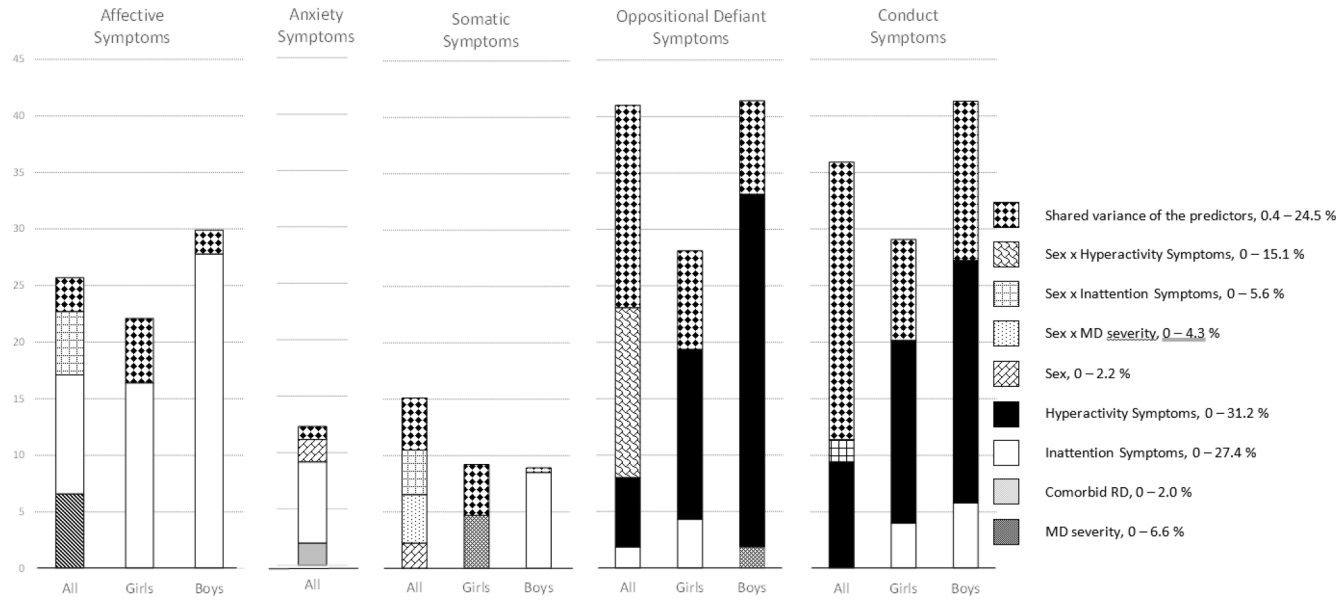

Fig. 1. Percentages of the Explained Variances Related to Different Factors. (Separate bar charts presented for girls and boys when sex was a significant moderator, that is, when the weight of different factors was different for girls and boys.).

Table 4
Results of the regression analyses for the predicting symptoms in the externalizing scales.

	Oppositional Defiant Problems			Conduct Problems		
	R^2 change	β	95 % CI	R^2 change	β	95 % CI
Step 1	**0.025***			**0.017***		
MD severity		−0.016*	−0.029–0.003		−0.007	−0.014–.001
Comor. RD		−0.025	−0.053–.002		−0.014	−0.030–.002
Step 2	**0.260*****			**0.313*****		
MD severity		−0.009	−0.021–.002		−0.002	−0.008–.004
Comor. RD		−0.012	−0.036–.012		−0.007	−0.020–.006
Inattention		0.009*	0.000–.019		0.016***	0.007–.025
Hyperactivity		0.028***	0.021–.035		0.148***	0.117–.179
Step 3	**0.011***			**0.000**		
MD severity		−0.009	−0.020–.002		−0.002	−0.008–.004
Comor. RD		−0.014	−0.038–.010		−0.007	−0.020–.006
Inattention		0.013**	0.003–.021		0.015**	0.005–.025
Hyperactivity		0.026***	0.020–.033		0.150***	0.117–.183
Sex		0.029*	0.005–.054		−0.003	−0.017–011
Step 4	**0.108*****			**0.028*****		
MD severity		−0.009	−0.019–.002		−0.002	−0.008–.004
Comor. RD		−0.011	−0.033–.011		−0.006	−0.019–.007
Inattention		0.011*	0.000–.022		0.009	−0.004. –022
Hyperactivity		0.015***	0.008–.022		0.098***	0.040–.156
Sex		0.017	−0.006–.040		−0.004	−0.018–010
Sex x Inatt.		−0.003	−0.028–.022		0.017*	0.001–.033
Sex x Hyp.		0.062***	0.044–.079		0.014	−0.002–031
Total R^2	**0.404; $F(7,352) = 34.096$*****			**0.359; $F(7,351) = 28.120$*****		

* $p < 0.05$, ** $p < 0.01$, ***<.001.

explained by hyperactivity (20–22 %) in oppositional defiant and conduct problem symptoms.

Similarly as above, effect of sex (RQ2) was analyzed with further two steps. Step 3 showed that sex had a significant direct effect on oppositional defiant symptoms boys showing more problems than girls, but no direct effect was found for conduct problem symptoms. However, the effect of sex was no longer significant after adding the sex x hyperactivity interaction term into the model in step 4. Also, sex moderated the effect of hyperactivity in oppositional defiant symptoms and inattention in conduct problem symptoms. Hyperactivity was a significant predictor of oppositional defiant symptoms in both sexes, but the effect was larger in boys (21 % vs. 11 % in boys and girls, respectively). The effect of inattention on conduct problem symptoms was significant only for boys.

4. Discussion

The present study aimed to gain an understanding of the associations between the behavioral–emotional symptoms and inattention and hyperactivity among children with MD. With linear hierarchical regression analyses we studied to what extent variability in inattention or hyperactivity was related to the amount of behavioral–emotional symptoms after controlling for the severity of MD and comorbid RD, and whether sex was directly related to these symptoms or did it moderate the possible associations of inattention or hyperactivity with them. The study provided insight into these relations, first, by showing that teacher-rated inattention and hyperactivity had substantial contribution on the number of behavioral–emotional symptoms. Second, associations of inattention and hyperactivity to behavioral–emotional symptoms were somewhat different: inattention was associated mainly with internalizing symptoms whereas hyperactivity was associated with externalizing symptoms. And third, sex had both direct and moderating effects. The effects of the control variables, that is, severity of MD and comorbid RD, were minimal, and they were mainly negated by inattention and hyperactivity.

The percentages of children demonstrating teacher-related behavioral–emotional problems (i.e., their scale score was above 1.5 SDs) were high, ranging from about 10–73 % among girls and from 16–56 % among boys. The highest percentage was found in inattention problems. Several of the previous studies have not reported percentages of children's inattention or hyperactivity problems separately as they have been combined with the attention problem scale or percentages of ADHD have been reported. However, some of the recent studies have reported results like ours. NoackLeSage et al. (2019) found that inattention was negatively correlated with mathematics achievement in their sample comprising children attending an outpatient clinic, and Wakeman et al. (2023) concluded that difficulty in mathematics was associated with higher levels of inattention than hyperactivity. These findings support the stance that hyperactivity and inattention should be assessed and analyzed separately and suggest that especially inattention is associated with difficulties in mathematics.

Excluding inattention and hyperactivity, which were used as explanatory variables in the present study, the most worrying percentages were found in affective problems (girls: 41.5 %; boys: 37.6 %) and in anxiety problems (girls: 26.7 %; boys: 33.6 %). The high percentages were to be expected, as we have earlier reported percentages of the same data based on parent and teacher reports (Aro et al., 2022), and high co-occurrences of behavioral–emotional problems among children with MD have also been reported by others (Auerbach et al., 2008; Willcutt et al., 2013). In general, the percentages in our data were of the same size as in earlier studies, but the percentages for the affective and anxiety problems were somewhat higher. The present results is partly in line with Willcutt et al. (2013), who found that anxiety and depression were most common among children with both RD and MD, although in our data, comorbid RD decreased anxiety symptoms. Our results concerning anxiety and somatic problems among boys concord with Graeffen et al.'s (2015) findings on higher ratings of internalizing problems among boys with MD. However, our results did not fully confirm the suggestion of Wu et al. (2014) that children who are at the lowest levels of mathematics achievement may be at greater risk for having conduct problems or oppositional defiant disorder, as these were not the most common problems in our clinical sample. Based on the existing evidence, it can be concluded that, in addition to inattention, especially affective and anxiety symptoms commonly co-occur with MD, and they should be recognized by the teachers.

The present results indicated that symptoms of both inattention and hyperactivity have a noticeable contribution to the amount of behavioral–emotional symptoms. This is line with previous research conducted with population samples. For instance, Hollingdale et al. (2022) showed recently that children with greater hyperactive/inattentive traits had significantly greater conduct and emotional (i.e.,

internalizing) problems. In our data among those with MD, the associations of inattention and hyperactivity to behavioral–emotional symptoms differed: inattention symptoms had effects on affective, anxiety, and oppositional defiant symptoms whereas hyperactivity had strongest effect on oppositional defiant symptoms. Thus, our finding concerning inattention somewhat differs from the one reported by Visser et al. (2020), who showed that inattention fully accounted for the relationship between mathematics and conduct disorder in a population-based sample. The present results concord with findings among those with reading difficulties as Carroll et al. (2005) found that the relationship between literacy difficulties and depressed mood was accounted for by inattentiveness. The association between hyperactivity and behavioral–emotional symptoms have not been reported previously among children with MD, but in the present data, it was found to contribute solely to externalizing symptoms. The effect was clearest on oppositional defiant symptoms among boys. In sum, the present finding suggests that inattention, in particular, may have a role in the development of internalizing problems, especially among boys (see below). This underlines the need of longitudinal research targeting especially the dynamics between inattention and later internalizing symptoms among children with MD. These studies should adopt and test a comprehensive theoretical model of how inattention is related to self-regulatory skills and how these moderate the effect of inattention on internalizing emotional-behavioral problems over the course of development.

Sex had a main effect on affective and somatic symptoms in our data: affective symptoms were more common among boys, somatic symptoms were more common among girls. In somatic symptoms and conduct problems, inattention increased symptoms only among boys, and in affective symptoms, a larger portion of variance was explained by inattention among boys. Similarly, hyperactivity increased symptoms of oppositional defiant symptoms, especially among boys. Thus, the findings suggest that the comorbidity of MD and ADHD symptoms may have more detrimental effects for boys than for girls. Previously, it has been shown that boys are prone to oppositional defiant and conduct disorders and ADHD (Altemus et al., 2014; Martel, 2013). Our findings suggest that these symptoms among those with MD may be related to a high level of hyperactivity or inattention.

4.1. Limitations

When interpreting our findings, it should be borne in mind that the CLD serves children who have been found to show learning-related difficulties in the school, but those with psychiatric problems as their *primary* problem are not referred to the CLD. Therefore, it can be supposed that even higher percentages would have been found if those children were also referred. However, it is also plausible that children with co-occurring learning and behavioral–emotional problems are more easily referred to assessment outside the school. The number of boys in the sample exceeded that of girls which is typical for clinical samples as the referral bias often occurs leading to different sex-distribution that there would be in a population-based sample. The possible referral biases can, unfortunately, only be speculated. It should be noted that we did not use a diagnostic interview but based our definition of clinical relevance on the number of symptoms and cut-off of 1.5 SDs, which means that the expected percentage of children with a problem would be about 7 % in the population. Some of the earlier studies used a more rigorous diagnostic procedure; for example, Willcutt et al. (2013) used the diagnostic interview and ASEBA. It should also be noted that cut-off score is always arbitrary to some extent and consensus is lacking, and the findings are always dependent of the cut-off score used. Despite the differences in the data and in the diagnostic procedures, the percentages of behavioral–emotional problems found in different studies are alarmingly high and indicate that MD too often co-occurs with behavioral–emotional problems. For the educators and clinicians, it would seem the present results are most relevant for the children with severe MD. It would be of further interest to determine whether these conclusions hold true for children or adolescents who may experience difficulties associated with higher-level mathematical skills.

Our data was gathered in a clinical setting for several years, and it is possible that during these years there has been an increased awareness among teachers about both behavioral–emotional problems and MD. On the other hand, there are also probably changes in the student behavior and in can be supposed that teachers make their assessments in relation to their current student population. However, as we noticed that the teachers reported fewer conduct problems in the last subsample assessed 2015–2017 we conducted additional analyses without the last subsample, but no change occurred in our results. It is also reasonable to take into consideration that teachers may have misinterpreted or confounded behavioral–emotional problems, especially inattention, with MD. They may be difficult to discern, especially in classroom situations where academic deficits may also influence child's working memory and attentional capabilities. Observational research in the learning context might shed light on both child behavior and teacher's interpretation of it. It should be noted, however, that the teachers of the present study were classroom teachers who saw the child also during subjects other than mathematics.

Unfortunately, our data did not allow for analyzing causal relations; and studies using longitudinal design are needed. Previous studies using large longitudinal community samples have reported somewhat inconsistent results. Darney et al. (2013) found that combination of academic and behavior problems (i.e., aggressive behavior, oppositional behavior, attention problems) at school entry were associated both with poorer mathematics scores and use of mental health services eleven years later, but use of mental health services was not increased among those with initially only academic problems. Somewhat differentially, there are indications that children with poor mathematics skills are more likely to later display both internalizing (Lin et al., 2013) and externalizing behavior problems (Wakeman et al., 2023; see also Aro et al., 2019 on adult-age outcomes). Thus, more research is needed on the possible reciprocal causal associations. Longitudinal studies analyzing these connections among unselected populations would also complement the understanding gained from research among children with problems in mathematics.

4.2. Conclusions and implications

The current results indicate that a significant percentage of children with MD exhibit behavioral–emotional problems, the most pronounced being affective and anxiety symptoms, in addition to inattention. The final regression models indicated the effects of inattention and hyperactivity symptoms were significant for most of the symptoms after controlling for severity of MD and comorbid RD. This cautions against the assumption that MD alone accounts for behavioral–emotional symptoms. Overall, our results suggest that the two ADHD symptoms make a relevant, but partly different, contribution to the manifestation of other behavioral–emotional problems among children with MD, and the effects were more prominent among boys. This shows the necessity to analyze their contributions separately in future studies and in educational assessment. Furthermore, the results underscore that we should not focus only on those with a diagnosed ADHD, because subclinical symptoms may still be of major relevance and pose a child with MD to a risk for emotional distress. However, the extent to which the severity of mathematical difficulty is caused by inattention and hyperactivity symptoms remains unclear.

The findings imply that, in educational settings, the psychological well-being of children with MD should be carefully monitored, and both preventing and intervening support should be provided, and the support should target attentional and emotion regulation skills in addition to mathematics. Similarly, clinicians working in child or adolescent psychiatric care should consider possible mathematical disabilities and inattention and hyperactivity symptoms as they have implications for

type of care needed.

The future research should aim to better understand the mechanisms through which hyperactivity and inattention are associated with behavioral–emotional problems among children with MD. Similarly, better understanding is also needed on developmental processes through which behavioral and emotional characteristics of the child influence academic outcomes – and vice-versa. Based on the existing evidence, the co-occurrence is not caused by chance; rather, the findings refer to underlying common liabilities or causality between the symptoms. For instance, shared cognitive characteristics, such as deficits in executive functions or working memory, or temperament-related features, such as emotionality or shyness, may partly explain associations between inattention and internalizing symptoms, and finally their relations to deficits in mathematics. A new generation of research is needed to consider developmental problems as a complex phenomenon entailing consideration of the interactive effects of the emotional, cognitive, neural, and academic characteristics of the child and diverse environmental factors. This kind of holistic approach can produce knowledge necessitated for developing effective interventions.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Further reading

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