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Inattention negatively moderates the effectiveness of a mathematics intervention in low performing primary school students

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Research suggest that attention skills play distinct roles in children's acquisition of mathematics. Despite a growing number of mathematics interventions in general, little research has been devoted to mathematics interventions for students with attention/hyperactivity problems (ADHD). Extant literature suggests lower benefits of mathematics interventions for students with ADHD symptoms. This study aimed at investigating the influence of ADHD on the effectiveness of a mathematics intervention. In a single-case research design, a total of N = 10 students in Grades 2 and 4 with varying ADHD profiles were observed and trained in an ABAB-design with a computer-cased mathematics intervention. Intervention and progress monitoring were administered twice a week. The intervention showed heterogenous effects ranging from no to substantial learning progress during the intervention phases. Hierarchical piecewise regression models revealed lower learning progress for students with all ADHD symptoms as well as isolated attention difficulties. However, students with isolated hyperactivity but no attention difficulties did not respond less to the intervention. As a conclusion, mathematics interventions are supposed to address students with attention deficits more explicitly.

KEYWORDS

ADHD, inattention, math difficulties, interventions, single-case research design

1 Introduction

Attention skills play a pivotal role in shaping children's acquisition of mathematics, guiding their cognitive development and learning process (Tosto et al., 2015; Orbach et al., 2020; Kanevski et al., 2022). These skills, encompassing focused attention, sustained concentration, and selective filtering, serve as the cognitive foundation upon which mathematical concepts are built (Peng et al., 2016). By fostering the ability to engage with mathematical problems, explore patterns, and manipulate numbers, attention skills lay the groundwork for a child's mathematical proficiency and comprehension.

Recent epidemiological studies have provided evidence for a substantial comorbidity between attention-deficit/hyperactivity disorders (ADHD) and low math performance in school-aged children (Swanson, 2012; Willcutt et al., 2013; Haberstroh and Schulte-Körne, 2019; Visser et al., 2020). Based on the diagnostic criteria of the Diagnostics and Statistical Manual of Mental Disorders – Fifth Version (DSM-V) [American Psychiatric Association (APA), 2013], Visser et al. (2020) reported that students with low math performance were almost four times as likely to show ADHD symptoms than students without any learning difficulty. In a meta-analysis, Haberstroh and Schulte-Körne (2019) found an overall effect size of g = 0.73 for group differences in attention between students with and without mathematics difficulties (MD).

Following international classification systems such as the DSM-V, ADHD refers to a neurodevelopmental disorder that is characterized by three main symptoms. First, attention deficits lead to a reduced ability to focus on a specific topic and a higher probability of being distracted by irrelevant stimuli. Second, students with ADHD have a higher need for physical activity and tend to show more body motion (so-called hyperactivity). Third, ADHD is associated with difficulties in inhibition, leading to a more impulsive behavior. Whereas, hyperactivity and impulsivity often occur, attention deficits regularly occur isolated. Thus, ADHD can be classified into three main subtypes, an inattentive subtype, a hyperactive/impulsive subtype, and a combined subtype (DSM-V).

Explanation models for the comorbidity between ADHD and MD discussed in the literature often refer to central executive functions (CEF). CEF cover crucial cognitive processes involved in planning and monitoring actions, such as inhibition, cognitive flexibility, and working memory ADHD is often associated with lower central executive function (CEF) resources (Doyle et al., 2005). As a consequence, lower CEF resources affect performance in math tasks (Holmes et al., 2021). For example, children with ADHD show difficulties in carrying out solution algorithms, inhibiting irrelevant information, or storing intermediate results in the short-term memory (Smith and Jonides, 1999; Orbach et al., 2020; Kanevski et al., 2022). An implication of lower CEF resources is, that students with ADHD symptoms struggle more to focus on a given task and are more likely to be distracted (Peng et al., 2016). In mathematics classes students with ADHD face specific difficulties, as they struggle with following instruction and acquiring new mathematical knowledge (Friso-van den Bos et al., 2013; Tosto et al., 2015). To summarize, ADHD affects students in acquiring, performing and monitoring math performance.

Obviously, all explanations for the comorbidity of ADHD and low math performance discussed above draw predominantly on inattention as core characteristic of ADHD. Empirical evidence supports the notion that inattention is more relevant for math performance. For example, Willcutt et al. (2013) report an association between inattention and low math performance twice as high as for mean hyperactivity/impulsivity and low math performance. Orbach et al. (2020) did not find any significant relation between math performance and hyperactivity/impulsivity, whereas inattention had a substantial effect on math performance. In a meta-analysis, Tosto et al. (2015) found only three out of eight studies reporting a significant association between math performance and hyperactivity/impulsivity, whereas nine out of eleven studies reported significant associations between math performance and inattention.

To summarize, ADHD and in particular inattention is associated with low math performance. Extant studies investigating the relationship between math performance and ADHD focused on learning outcomes. However, there is little to no evidence regarding the moderation between the core symptoms of ADHD and the effectiveness of individualized math interventions in school settings. Knowledge about such moderation can inform whether a student with math difficulties truly has a deficit in mathematical skills or if their math difficulties can be attributed to inattention. In the context of preventive action plans such as Response to Intervention (RtI; e.g., Grosche and Volpe, 2013), this information is crucial as a student may respond differently to math interventions depending on whether they genuinely have deficits in mathematical skills or additionally exhibit inattentiveness. Therefore, the inattentiveness of students should be considered when planning and selecting an appropriate and targeted math intervention. Inattention is very likely to affect effects of teaching in a classroom setting, since individual students might digress or be distracted from instruction without the teacher noticing (Groenewald et al., 2009; Moldavsky et al., 2012). In contrast, students with lower attention capabilities are unlikely to be distracted or digress from the intervention in an individual setting.

To investigate the effects of ADHD on a math intervention within a RtI framework, a single-case research design has several advantages. First, the design allows to investigate both immediate effects (so-called level effects) and continuous effects (so-called slope effects) (Huitema and Mckean, 2000). Therefore, the design allows to assess both immediate treatment impact and individual progress over time. Second, the target group – students with low math performance and ADHD symptoms – is comparably small, so that it is unlikely to find adequate samples or control group interventions (e.g., pre-post designs) (Smith, 2012). A single-case design is not likely to be invalidated by a lack of comparability of control and intervention group, because they draw on intraindividual comparisons (performance during the baseline vs. during the intervention). In fact, the baseline phase without intervention serves as a mean to control for learning progresses without a specific intervention. Thus, single-case designs are particularly adequate for very specific target groups, such as students with low math performance and ADHD (Smith, 2012). Third, individual intervention effects can be assessed and are not disguised in group means. Individual intervention effects can provide more detailed information on the moderation of intervention effects (Riley-Tillman et al., 2020). Thus, an investigation of the dependency of intervention effects on ADHD in a single-case design can significantly add on the extant literature on the relevance of ADHD on math performance.

Two main research questions (RQ) are supposed to guide the present study:

(RQ1) To what extent does ADHD (i.e., symptom of inattention, hyperactivity, and impulsivity) moderate the effectiveness in terms of acquisition and maintenance of a math intervention regarding level and slope?

(RQ2) How do the core characteristics inattention and hyperactivity/impulsivity affect the intervention effects in terms of acquisition and maintenance regarding level and slope?

2 Methods

2.1 Sample

A total of $N = 10$ students from three German primary schools participated in the present study. Whereas, six students were in Grade 4, four students were in Grade 2. Seven students were monolingual German speakers and three students were bilingual. However, all students understood German well enough to follow instructions of the tests and the intervention. Two of the students attended a special education school. Table 1 comprises the diagnostic information of the students at the beginning of the study.

Prior to the intervention, 68 students from the participating schools were screened for low math performance. Inclusion criterion for low math performance was a performance in a standardized and normed math test (HRT, see below for description) of at least one standard deviation below the mean (i.e., a *T*-value of 40 or below). All nine students of the participating classes, who met the inclusion criteria, were included in the current study. In addition, one child (Harold) was included who showed below-average math performance ($T = 43$) and comparably strong ADHD symptoms. This child was included to increase the variety of ADHD symptoms in students with below-average math performance on the sample.

None of the participating students had been diagnosed with ADHD beforehand. Therefore, neither behavior *therapy* nor medical treatment (e.g., methylphenidate) was applied during the study.

Written consent of the parents was obtained beforehand the study. Both students and parents were informed in advance that the data collected would be published anonymously. The local ethics committee of the University of Wuppertal approved the study (Approval number MS/AH 200925 Herzog).

2.2 Instruments

2.2.1 HRT

We used the arithmetic subscale of the Heidelberger Rechentest 1–4 (HRT; Haffner et al., 2005) to assess the students' math achievement prior to the intervention. The arithmetic subscale of the HRT covers addition, subtraction, completion tasks, and number comparison in Grade 2. In Grade 4, multiplication and division were assessed, too. Every subtest consists of 40 tasks. Students have 2 min per subtest to solve as many tasks as possible. Based on the raw scores (number of correctly solved tasks), grade-level-adjusted *T*-values were derived. In the norming sample, the HRT showed a good reliability ($r_{tt} = 0.77–0.89$).

2.2.2 CODY-LM

The individual development of the students' math achievement was assessed with the CODY-LM (Schwenk et al., 2017). The CODY-LM is a computer- and progression-based assessment that covers addition, subtraction, and ordering of numbers. Based on the number of correctly solved tasks and the reaction times, a raw score was obtained. The progression-based assessment was administered twice per week. Thus, the students were assessed between 20 and 26 times. The CODY-LM test is part of the intervention Meister Cody (see below). Schwenk et al. (2017) report good reliability ($r_{split-half} = 0.87–0.93$).

2.2.3 CBCL

Students' ADHD symptoms were assessed with the German version of the Teacher Report Form of the Child Behavior Checklist (TRF-CBCL; Döpfner et al., 2015). The teachers of the students rated their ADHD symptoms as well as regarding the two core symptoms inattention and hyperactivity/impulsivity. Given the age group, a self-reported questionnaire was not applicable. The CBCL showed good reliability in a norming sample regarding attention problems ($r_{tt} = 0.93–0.94$).

2.3 Intervention

Students' math skills were trained with the computer-based math intervention *Meister Cody Talasia* (Kaasa Health, 2013). Based on robust indicators approach that fosters subskills that are highly predictive for math achievement, Meister Cody covers counting skills, magnitude comparison, number line estimation, simple addition and subtraction, and subitizing. An ongoing story line including several protagonists leads the students through the intervention. Meister Cody is adaptive, which means that the actual exercises in the intervention are selected based on an initial assessment.

The intervention was conducted on a tablet in a quiet separate room in the schools. Three well-trained undergraduate student instructors conducted the intervention. Prior to the study, the student instructors had passed exams in a module on diagnostics in special-education including a practical seminar and another module on intervention methods for students with MD. In preparation of the intervention, the student instructors were given detailed information on the used tests and the intervention program covering theoretical backgrounds as well as the practical usage. During the intervention phases (see design), the intervention was administered two times per week. Therefore, the students received 10–12 training sessions ($M = 11.20$; $SD = 0.87$). One training session lasted approximately 20 minutes. During the training sessions, the students completed several short exercises on different skill as described above. All instructions during the intervention sessions were given verbally through the tablet. Therefore, the intervention is highly standardized. For this reason, we assume a high implementation fidelity.

Kuhn and Holling (2014) report a positive effect of Meister Cody on students' math performance in general. Compared to a passive control group, students treated with Meister Cody showed significant bigger performance increases ($d = 0.54$). In their study, Kuhn and Holling (2014) give no information regarding the effectiveness of Meister Cody for students with ADHD, as ADHD had not been assessed. In a single case study, Herzog and Casale (2022) observed a vast heterogeneity in effectiveness when applying Meister Cody to students with and without emotional and behavior difficulties. Whereas, some students benefited significantly from the intervention, others were non-responders. Given this heterogeneity, no significant overall training effect was found. The

TABLE 1 Overview of the diagnostic information of the participating students.

Student[1]	Age[2]	Grade	Gender	HRT (T-value)	ADHD[3]	Inattention[3]	Hyperactivity/ impulsivity[3]
Anton[4]	10;3	4	M	40	12	9	3
Bert[4,5]	11;2	4	M	23,5	20	16	4
Carl	7;10	2	M	31	5	5	0
David	7;10	2	M	28	8	8	0
Eric[5]	7;3	2	M	31	20	15	5
Fanny[5]	7;1	2	F	25	3	3	0
Gina	11;3	4	F	21	6	6	0
Harold	10;6	4	M	43	19	15	4
Ines	11;5	4	F	38	10	8	2
Jenny	11;10	4	F	35	3	3	0

*F, female; M, male; [1] Pseudonyms; [2] Age is given in years; months; [3] CBCL raw scores; [4] visited a school for special educational needs; [5] Bilingual children.

results of this study indicated that students with emotional and behavior difficulties benefit less from a mathematics training with Meister Cody (Herzog and Casale, 2022).

2.4 Design

To investigate the dependency of the intervention effects of Meister Cody on ADHD and its core characteristics, an ABAB-design with a multiple baseline was employed. This design exhibits high internal validity as it increases the likelihood of the assumption of a functional relationship between the intervention and the dependent variable being valid by implementing a withdrawal (A2 phase) and re-implementation (B2 phase) of the intervention (Kratochwill et al., 2010). Considering the potential moderation of effectiveness by inattention, and hyperactivity/impulsivity it is assumed that the learning and developmental effects observed in the B phase are not attributable to a gain in competence. Therefore, it is adeqaute to employ this design, which usually is atypical for examining continuous learning effects, to address our research questions.

In the A-phases (baseline; A1 and A2), students' math performance was monitored twice per week with the progression-based assessment (CODY-LM), but no intervention took place. Thus, in the second A-phase (A2), intervention paused (withdrawal). In the B-phases (intervention; B1 and B2), Meister Cody was employed additionally to the progression-based assessment. To account for external learning opportunities (e.g., regular teaching), the start of the intervention was staggered (Kratochwill and Levin, 2014). As a consequence, the fist A-phase lasted between 2 and 4 weeks per student. All other phases lasted 3 weeks.

With a sample size of $N = 10$ and measurement time points between 20 and 26 per student, the sample size of the study is above average (Shadish and Sullivan, 2011). A *post-hoc* power analysis confirmed that the sample size is sufficient to detect even small intervention effects ($d = 0.2$).

2.5 Analysis strategy

Regarding the effectiveness of an intervention, an ABAB-design offers at least two analysis paths (McDougale et al., 2020). First, the effects of the acquisition of new mathematical knowledge (A1 vs. B1 and B2) can be investigated. Acquisition refers to the effectiveness of the intervention to gain new mathematical competencies after the start of the intervention. Second, the maintenance of new knowledge (B1 vs. A2) can be investigated. Maintenance refers to the sustainability of the intervention after its end. In this study, intervention effects regarding acquisition and maintenance as well as their dependency on ADHD symptoms are investigated.

Analysis was conducted with the *scan* package for the open-source software R (Wilbert and Lüke, 2021). Overall intervention effects were assessed by comparing the students' performance in the progression-based assessment during the baseline phases vs. the intervention phases. Hedge's g was estimated to provide a measure for the effect of the intervention phases on the performance (Shadish et al., 2014). To test for intervention effects and their moderation through ADHD symptoms, hierarchical piecewise regression models (HPLM) across all students were employed (Moeyaert et al., 2023). In these models, the math performance in the progression-based assessment is predicted by the phase and the measurement time point as well as additional variables such as ADHD symptoms. HPLM have the advantage that interaction effects can be added to investigate the effect of additional variables on the effectiveness. To account for individual differences, random effects were added to the HPLM (Moeyaert et al., 2023). Analysis strategy regarding acquisition and maintenance was parallelized: General intervention effects were addressed first, before moderation effects of overall ADHD symptoms (ADHD), inattention (IN) and hyperactivity/impulsivity (HI) were added.

TABLE 2 Descriptive statistics of the intervention phases.

Student	A1			B1			A1			B1			Hedge's g
	M	SD	Md	M	SD	Md	M	SD	Md	M	SD	Md	
Anton	139.75	56.85	160.0	141.83	22.86	138.5	145.83	25.53	140.0	144.00	15.38	149.0	−0.02
Bert	62.25	13.50	63.0	57.50	16.16.	61.0	74.33	13.57	76.5	69.20	25.82	62.0	−0.36
Carl	19.00	23.41	8.0	21.33	19.10	14.0	61.00	18.65	66.0	75.83	22.71	73.0	0.13
David	10.83	9.99	8.5	15.33	23.53.	6.0	17.50	8.36	21.0	17.67	15.63	16.5	0.15
Eric	35.17	11.16	33.0	54.50	16.39	52.5	79.40	29.05	68.0	92.67	9.91	91.5	0.65
Fanny	38.38	13.75	41.0	57.50	30.98	57.0	112.33	10.52	109.0	99.83	14.08	102.0	0.22
Gina	85.75	18.82	85.5	127.00	19.56	118.0	111.20	13.24	105.0	129.50	19.86	131.0	1.41
Harold	118.50	27.76	120.5	123.40	15.47	121.0	152.00	33.53	146.0	130.60	22.66	134.0	−0.23
Ines	149.62	32.38	146.0	164.00	17.71	156.0	199.00	12.52	197.5	176.40	19.18	171.0	0.13
Jenny	106.00	51.11	115.0	138.20	41.90	13.0	187.50	12.71	188.5	204.00	53.30	220.00	0.59

*A1, first A-phase; B1, first B-phase; A2, second A-phase; B2, second B-phase; M, mean; SD, standard deviation; Md, median.

3 Results

3.1 Descriptive statistics

The descriptive statistics of the students' performance in the four phases of the study reveals a broad heterogeneity regarding the intervention effects. Whereas, the majority of the students showed higher performance means and medians in the first B-phase than in the first A-phase, only two students showed substantial performance increases exceeding one standard deviation. Interestingly, nine students showed further performance gains during the second A-phase, during which intervention was paused. In seven cases performance gains from the fist B-phase to the second A-phase exceeded one standard deviation. Finally, only four students showed additional performance gains during the second B-phase, when intervention was continued. In two cases, these gains exceeded one standard deviation. Across the whole study, five students showed performance gains in both B-phases, whereas four students showed performance increases in all phases. A graphical representation of the students' learning trajectories can be found in the Supplementary material.

The heterogeneity in intervention effects can also be found when comparing the performance in the progression-based assessment during baseline and intervention phases. Whereas, three students (Eric, Gina, and Jenny) showed considerable performance gains during the B-phases (Hedge's $g = 0.59$ - 1.14), four (Carl, David, Fanny, and Ines) students showed only small performance gains (Hedge's $g = 0.13$ - 0.22). Three students (Anton, Bert, and Harold) even showed even lower performance in the B-phases (Hedge's $g < 0$). Given these results, the intervention was only for a third of the sample substantially effective. The descriptive statistics are summarized in Table 2.

3.2 Acquisition

The general acquisition effects were addressed (model 1) before investigating the moderation of acquisition intervention effects through ADHD symptoms (models 2–4). Therefore, only slope and level effects were added to model 1. In model 2, overall ADHD symptoms and interaction effects with level and slope were added to the model. ADHD core characteristics and interaction effects with level and slope were added to model 3 (inattention) and model 4 (hyperactivity/impulsivity). Reliability of the acquisition models was adequate (ICC = 0.680; Cicchetti, 1994).

Regarding the general acquisition effects, no significant level or slope effects were found. ADHD and its core characteristics had no direct effects on math performance. Significant interaction effects were only found for overall ADHD symptoms and inattention regarding the slope. However, hyperactivity/impulsivity showed not significant interactions. Table 3 comprises the results of the acquisition HPLM.

3.3 Maintenance

Regarding the maintenance of intervention effects, the analysis procedure was parallel to the acquisition effects: Model 5 describes the general maintenance effects, while models 2 to 4 address the moderation of the maintenance effects through overall ADHD symptoms, inattention, and hyperactivity/impulsivity. Reliability of the maintenance models was good (ICC = 0.789: Cicchetti, 1994).

Regarding the maintenance of intervention effects when intervention was paused, no significant effects were found. That means that the end of the intervention did not lead to a considerable decrease in level or slope. Neither did ADHD nor one of its core characteristics show any direct or interaction effect. Table 4 comprises the results of the maintenance HPLM.

4 Discussion

This study aimed at investigating the moderation of intervention effects in terms of acquisition and maintenance through overall ADHD symptoms (RQ1). Overall ADHD symptoms moderated the slope effect regarding acquisition

TABLE 3 Parameters of the acquisition HPLM.

Parameter	Model 1	Model 2	Model 3	Model 4
Fixed effects	b	b	b	b
Intercept	62.142*	63.394*	63.679*	62.722*
Trend	5.888*	5.496*	5.403*	5.711*
Level	−15.024	−13.880	−13.619	−14.486
Slope	−1.740	−1.397	−1.308	−1.597
ADHD		7.080		
ADHD × Level		−1.779*		
ADHD × Slope		−1.089		
IN			4.398	
IN × Level			−1.992*	
IN × Slope			−0.787	
HI				13.128
HI × Level				−1.188
HI × Slope				−1.702
Random effects				
Intercept	47.811	47.996	47.924	47.355
Residual	26.669	25.857	25.704	26.236

*ADHD, Overall ADHD symptoms according to the ADHD subscale of the CBCL; IN, inattention; HI, hyperactivity/impulsivity; *p < 0.05.

TABLE 4 Parameters of the maintenance HPLM.

Parameter	Model 5	Model 6	Model 7	Model 8
Fixed effects	b	b	b	b
Intercept	84.070*	83.979*	83.964*	84.038*
Trend	2.594	2.624	2.629	2.602
Level	10.650	10.594	10.564	10.653
Slope	−0.670	−0.692	−0.676	−0.686
ADHD		−0.548		
ADHD × Level		−0.201		
ADHD × Slope		−5.211		
IN			−3.726	
IN × Level			−0.336	
IN × Slope			−6.015	
HI				7.165
HI × Level				0.156
HI × Slope				−3.013
Random effects				
Intercept	52.364	52.368	52.066	52.086
Residual	22.952	22.774	22.698	22.912

*ADHD, Overall ADHD symptoms according to the ADHD subscale of the CBCL; IN, inattention; HI, hyperactivity/impulsivity; *p < 0.05.

significantly. Students with higher ADHD symptoms showed less performance increase over both intervention phases. However, no interaction with level effects were found. Moreover, overall ADHD symptoms did not moderate maintenance effects. When taking a closer look at the core characteristics of ADHD, inattention and hyperactivity/impulsivity (RQ2), only inattention moderated acquisition slope effects significantly and negatively. Regarding maintenance of the new gained mathematical knowledge, no interaction with inattention was found. In contrast, hyperactivity/impulsivity did not moderate slope nor level effects regarding acquisition or maintenance. Referring to the three main ADHD subtypes [American Psychiatric Association (APA), 2013], the combined as well as the predominantly inattentive subtype apparently benefit less from a mathematics training with Meister Cody. However, the hyperactive/impulsive subtype appears to be not affected significantly.

Thus, the acquisition slope moderation through overall ADHD symptoms is predominantly driven by inattention, but not hyperactivity/impulsivity. This result is in line with extant studies on learning outcomes (Willcutt et al., 2013; Tosto et al., 2015; Orbach et al., 2020) and corroborates explanation models for the relation between ADHD and math performance.

Only slope intervention effects were moderated significantly by inattention. That means that more inattentive students benefited less from the intervention over time. As a consequence, Meister Cody is unlikely to help low performing and inattentive students to gain lacking mathematical knowledge. This finding is particularly interesting, because the intervention was conducted in an individual setting, in which digressing can be addressed very easily.

4.1 Limitations

At least four limitations need to be discussed in regard to this study. First, the intervention in this study showed little overall intervention effects. Six out of 10 students can be considered non-responders to Meister Cody. This result challenges the assumption that Meister Cody is a generally adequate math intervention for low performing students (Kuhn and Holling, 2014). As a consequence, the moderation of intervention effects found in this study can hardly be transferred onto other interventions. A possible explanation for the low response on the intervention in inattentive students could be that Meister Cody has too many distracting features, for example, the ongoing story line, the illustrations, and the tablet.

Second, assessing ADHD in students solely through teacher ratings may present certain limitations in providing a comprehensive understanding of the individual's condition. Relying solely on teacher perspectives may lead to an incomplete assessment, as teachers primarily observe the student's behavior within the classroom setting. However, ADHD symptoms can manifest differently in various contexts and may not be fully apparent in a structured classroom environment (Scahill and Schwab-Stone, 2000). The necessary inclusion of multi-informant approaches, such as parent and self-report assessments, becomes crucial in future studies to gather a more holistic view of the student's functioning (De Los Reyes et al., 2023).

Third, the study was conducted in a single-case design. Even though the single-case design chosen here to answer the questions has more strengths than weaknesses, and the number of individual cases and measurement time points is above average, (Shadish and Sullivan, 2011), the results are hard to generalize for a broader sample and need to be replicated. Moreover, potential generalizations can only be done for students with low math performance. The moderation of intervention effects in typical or high performing students through ADHD and its core characteristics might be different. Further studies in this regard are necessary.

Fourth, the intervention was settled in story about two children in a fantasy story. The graphical artwork of the intervention was inspired by traditional east Asian cultures. Some of the exercises were based on formats that are not common in German primary schools (e.g., subitizing tasks). To summarize, the intervention might have had low ecological validity to some of the students. Ecological validity (in terms of an appropriate fit of the contents and design of the intervention to the students' needs and prerequisites; Lambert, 2015) is an important characteristic for the effectiveness of a math intervention (Dennis et al., 2022).

4.2 Educational implications

The results of this study have implications regarding the use of math intervention in school. As students with a higher level of inattention seem to be disadvantaged in math interventions, specific intervention for this group of students appears to be necessary (for an example see Schulze et al., 2020). Such interventions are supposed to address difficulties in learning that inattentive students encounter. For example, training sessions need to be short, so that students can maintain focus throughout the session. In one session, contents and tasks should not differ too much to facilitate students with low shifting capacities to complete the session. It appears recommendable that the intervention materials (e.g., worksheets) are very plain and without irrelevant illustrations that might distract students. An individual setting and a face-to-face design might help both the students and the instructors to make sure that attention is given to the exercises.

Whereas, hyperactivity/impulsivity is often noticed by teachers and educators, inattention is more likely to be neglected (Groenewald et al., 2009; Moldavsky et al., 2012). As a consequence, not identified students with high levels of inattention are not given the treatment they need, even if it is available. A lower effectiveness of math interventions is an additional argument for the need for an effective and efficient assessment of attention capacities in schools.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ethikkommission der Bergischen Universität Wuppertal Gaußstraße 20, 42119 Wuppertal MS/BBL 210428 Herzog. The studies were conducted in accordance with the local legislation and institutional requirements. The participants' legal guardians/next of kin provided written informed consent for participation in the study and for the publication of any potentially identifying information included within the article.

Author contributions

MH: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. GC: Writing – review & editing, Writing – original draft, Methodology, Conceptualization.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2024.1276741/full#supplementary-material

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