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Do we need a special intervention program for children with mathematical learning disabilities or is private tutoring sufficient?

Abstract

The present study examined the effects of the remediation program Waterglass Intervention Program (WIP; Schlotmann, 2004) for children with mathematical learning disabilities (MLD) compared to the effects of private tutoring. In a pre-post-test control group design, the data of n = 26 children (age = 8.86, SD = 1.40) who attended the WIP and n = 20 children (age = 8.45, SD = 0.68) who received private tutoring was analyzed. Intervention outcomes were investigated using a standardized math achievement test, math school grades, as well as parents' judgements. Data analysis revealed that children who attended the WIP showed a greater improvement of math skills and maths grades compared to children who received private tutoring. 17 children treated with the WIP but only 2 children who received private tutoring reached a percentile > 29 at the end of the intervention course. According to ICD-10 criteria, these children would no longer receive an MLD diagnosis. Parents whose children attended the WIP specified higher gains for mathematical abilities but not for psychosocial functioning or MLD symptoms for their children than parents did for the private tutoring group. The results indicate that the WIP is more effective for the remediation of MLD compared to private tutoring.

Keywords

Mathematical learning disabilities; Private tutoring; Waterglass Intervention Program (WIP)

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Brauchen wir ein spezielles Interventionsprogramm für rechenschwache Kinder oder ist Nachhilfe genug?

Zusammenfassung

In der vorliegenden Studie wurde die Wirksamkeit des Förderprogramms Wasserglasmethode (WGM) zur Behandlung von Rechenschwäche (Schlotmann, 2004) mit der Wirksamkeit von Nachhilfe bei rechenschwachen Kindern verglichen. In einem Prä-Post-Kontrollgruppendesign wurden die Daten von n = 26 Kindern (Alter = 8.86, SD = 1.40), die mit Hilfe der Wasserglasmethode gefördert wurden und n = 20 Kindern (Alter = 8.45, SD = 0.68), die konventionelle Nachhilfe erhalten hatten, analysiert. Als abhängige Variablen wurden die Mathematikleistung, die Mathematiknote und die Einschätzung der Eltern jeweils zu Beginn und Ende der Intervention erhoben.

Die Datenanalyse zeigte, dass rechenschwache Kinder, die mit Hilfe der Wasserglasmethode behandelt wurden, einen größeren Zuwachs ihrer mathematischen Leistung und Mathematiknoten verzeichneten als Kinder, die Nachhilfe erhalten hatten. 17 Kinder der WGM-Gruppe, aber nur 2 Kinder der Nachhilfe-Gruppe erreichten am Ende der Intervention einen Prozentrang über 29. Bei Zugrundelegung der ICD-10 Kriterien würde bei diesen Kindern somit keine Diagnose Rechenschwäche mehr gestellt werden. Eltern, deren Kinder mit der Wasserglasmethode behandelt wurden, berichteten eine stärkere Verbesserung der mathematischen Kompetenzen, nicht aber der Symptomatik und der psychischen Gesundheit. Die Befunde deuten darauf hin, dass die Wasserglasmethode im Vergleich zu konventioneller Nachhilfe eine effektivere Methode zur Förderung bei Rechenschwäche darstellt.

Schlagworte

Rechenschwäche; Nachhilfe; Wasserglasmethode

1. Introduction

Mathematical learning disabilities (MLD) are defined by the impairment of the acquisition of arithmetic skills (Gersten, Jordan, & Flojo, 2005). Recent studies reported prevalence rates about 3–6% of all children throughout various countries (e.g., Hein, Bzufka, & Neumärker, 2000; Lewis, Hitch, & Walker, 1994; Mazzocco & Myers, 2003; Shalev, Auerbach, Manor, & Gross-Tsur, 2000). Typically, these studies use a discrepancy criterion specified by the International Classification of Diseases (ICD-10) published by the WHO (2005).

Longitudinal studies proved MLD to be quite stable over time as long as no intervention is applied (Jordan, Hanich, & Kaplan, 2003; Geary, Hoard, & Hamson, 1999; Shalev, Manor, Auerbach, & Gross-Tsur, 1998). Presumably, the ongoing mathematical deficits will affect school outcomes and everyday activities, such as handling money, negatively (McCloskey, 2007). Considering this, the demand for numeracy intervention programs becomes evident. Intervention studies are often limited to specific domains of school mathematics, only cover a relatively short intervention period, and usually apply to early school grades. Learning mathematics, however, requires the mastering of a whole set of different competencies. Besides this, measures often cover single mathematical domains (such as word-problems) only, and some do not contain grade norms at all. Therefore, these measures do not allow for conclusions about the degree of improvement in the sense of the mathematical functioning level as a whole. The aim of the present study was to investigate the effectiveness of the Waterglass Intervention Program (WIP), a program designed to enable children to catch up with their grade level of mathematics so that they would no longer be diagnosed with MLD.

1.1 Characteristic deficits of mathematical learning disabilities and their remediation

Children with MLD suffer from specific deficits and show several core symptoms. These cover procedural as well as conceptual knowledge. Many children with MLD show difficulties with counting and counting strategies (e.g., Geary, Bow-Thomas, & Yao, 1992; Geary, Hoard, Byrd-Craven, Nugent, & Numtee, 2007) even at preschool age (e.g., Aunola, Leskinen, Lerkkanen, & Nurmi, 2004), and many remain with immature counting principles (e.g., Geary et al., 1999; Geary et al., 2007). Some children with MLD also fail to make the transition from counting to memory-based arithmetic fact retrieval (e.g., Geary et al., 2007; Jordan et al., 2003; Jordan & Montani, 1997). This aspect outlines the most frequently referred to deficit (e.g., Geary, 1993; Geary & Hoard, 2001; Shalev & Gross-Tsur, 2001). When trying to solve simple arithmetic problems by retrieving the answer from memory, children with MLD usually commit more errors and take more time (Geary, 1993; Gross-Tsur, Manor, & Shalev, 1996). For solving calculation problems, they use counting more often than children with average achievement (e.g., Geary, 1990; Geary, Brown, & Samaranayake, 1991), and results often differ from the correct answer by one (Domahs, Krinzinger, & Willmes, 2008). Gaupp, Zoelch, and Schumann-Hengsteler (2004) reported difficulties with the denominational number system even in children with MLD of the third and fourth grade. Furthermore, children with MLD proved to have difficulties with mathematical word-problem tasks (e.g., Case, Harris, & Graham, 1992; Swanson & Sachse-Lee, 2001).

These results reveal that children with MLD show a wide range of deficits so that in most cases they will need support in more than one domain. As mentioned above, previous intervention studies have examined intervention effects of several mathematical domains addressing children with MLD. For example, Fuchs et al. (2010) applied an intervention program on strategic counting instruction to third-grade students with MLD. Compared to a non-tutored control group, students who attended the program for the duration of 16 weeks with 3 sessions per week showed higher fluency on number combination skills (simple arithmetic problems). In adolescent students, Hopkins and Egeberg (2009) improved addition fact retrieval by extended training. Several studies addressed the improvement of word-problem difficulties in children with MLD. More complex programs, which additionally address number combination skills or the meaning of the equal-sign, increased word-problem skills (e.g., Fuchs et al., 2009; Powell & Fuchs, 2010). Kaufmann, Handl, and Thöny (2003) trained six children with MLD on procedural and conceptual knowledge addressing all four basic mathematical operations for the duration of half a year, and found significant improvements on different mathematical skills such as retrieval of number facts, written calculation or arithmetic principles.

Kroesbergen and Van Luit (2003) conducted a meta-analysis of 58 intervention studies including 2,509 children with MLD up to the age of 12 to detect essential characteristics of effective interventions. Trainings which focused on basic mathematical skills showed the highest effect sizes. Results indicated that trainings should be administered individually, and it should be focused on direct instruction and self-instruction (e.g., quoted monologue) depending on the domain to be taught. For learning basic mathematical facts, direct instruction proved to be most effective; for the acquisition of problem-solving skills self-instruction methods were also effective. Although not all children show all of the illustrated deficits, these results lead to the conclusion that a training which addresses several of the aforementioned deficits and includes essential features of successful interventions in children with MLD will produce positive outcomes.

1.2 An intervention program for children with MLD

1.2.1 Theoretical background

The Waterglass Intervention Program (WIP; Schlotmann, 2004) was designed for children with MLD of all school-age groups. This program tries to integrate most domains of school mathematics so that children are able to reach grade level. The following description of the WIP does not claim completeness since the program is too complex to be explained in detail. Still, the main features are to be outlined (for further information see Schlotmann, 2004, 2009).

Theoretically, the program is oriented towards the triple-code-model of number representation (Dehaene, 1992). The triple-code-model states that numbers are internally represented in three different codes. The auditory-verbal representation form (e.g., “eight”) processes spoken and written numbers and constitutes the basis for counting and fact retrieval. The second module represents the visual Arabic number form (e.g., “8”) and is responsible for exact calculation. Within this module, numbers are precisely represented and can be manipulated based on the Arabic form. The third representation format is called the analogue magnitude code and contains knowledge about the numerical magnitude of numbers and quantities. For the execution of complex calculation procedures, information is translated back and forth between the modules. According to Dehaene, all representation formats can be impaired. The WIP tries to integrate all three formats to ensure the constitution of all representation types and the smooth interaction between them using a special manipulative. Manipulatives are dynamic objects that present opportunities for constructing arithmetical knowledge. They are required to enable children to shift from concrete manipulation of material to mental arithmetic (Uttal, Scudder, & DeLoache, 1997). The material was designed to allow the representation of all mathematical operations including the portrayal of fractions and decimals. In addition, the material should prevent children from ongoing counting strategies to solve mathematical problems and aid them to shift to higher order strategies. Trainers use standardized, cylindrical water glasses without any markers and colored water to display quantities and discrete numbers. Water is not countable, so children can no longer rely on pure counting. At the same time, it is possible to display numbers in a discrete way, which is essential for the understanding of the quantity-number linkage. Usually, manipulatives do not allow the display of imprecise quantities even though Krajewski and Schneider (2009) stated this comprehension to be crucial in the development of mathematical competencies. The manipulative material used in the WIP, however, allows the display of imprecise quantities and allows for the judgment of numbers by relational information alone (analog magnitude representation).

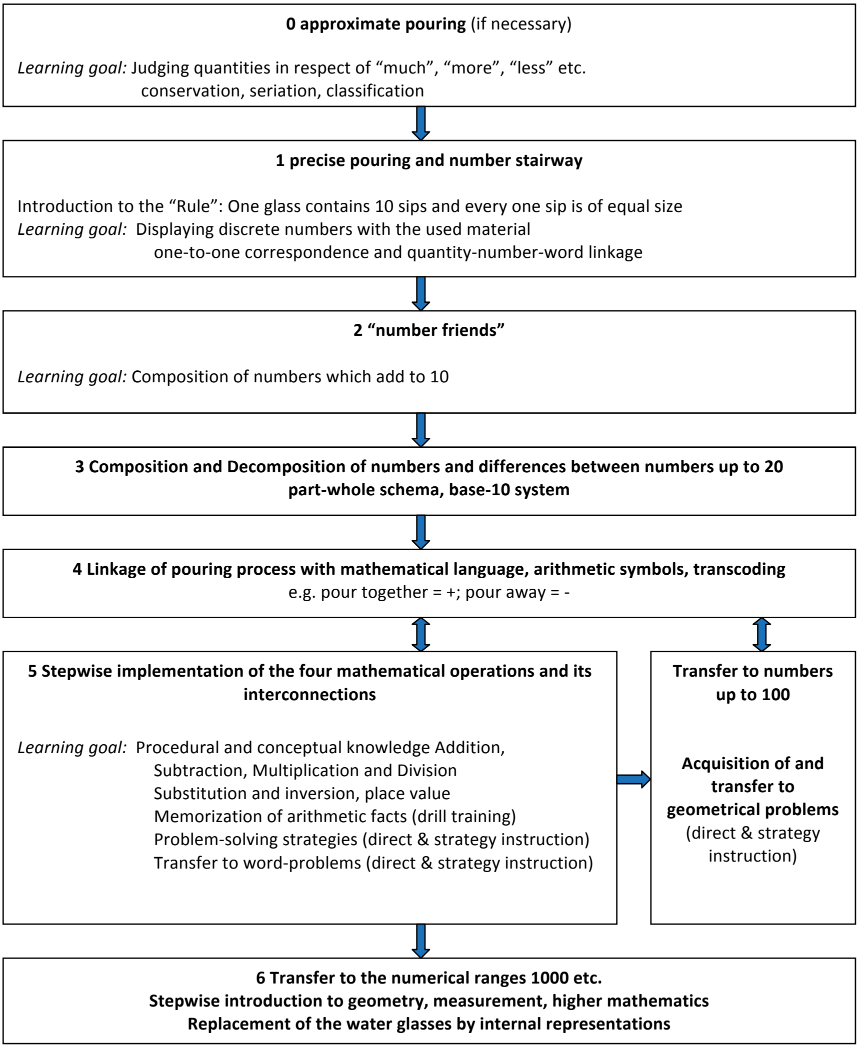
The visual-arabic representation format is meant to be addressed by transferring concrete calculation activities using the material into mathematical symbols. These are linked to mathematical language using verbal description and reflection of the calculation process. This marks the auditory-verbal representation format.

1.2.2 Intervention procedure

At the beginning of the intervention, children learn that one full glass of water contains 10 "mathematical sips" of equal size. Children thus have to develop a stable understanding of one-to-one-correspondence and come to realize that in each 10 are 10 single sips (ten different glass with one sip each poured together results in a full glass which is 10 again). One could assume that a child has to have an understanding of division to master this task. However, by applying the predetermined rule, they are able to build up this concept without understanding division. This step is picked up again later during intervention course when children are introduced to division.

In addition to these aspects, a glass always displays 10 and 0 as a reference point so children can also easily develop a relational understanding of numbers. Numbers get linked with the expansion of the water and the spatiotemporal dimension. High numbers require more time and more water to be produced than smaller numbers do.

Figure 1: Semi-hierarchical standard course of the Waterglass Intervention Program

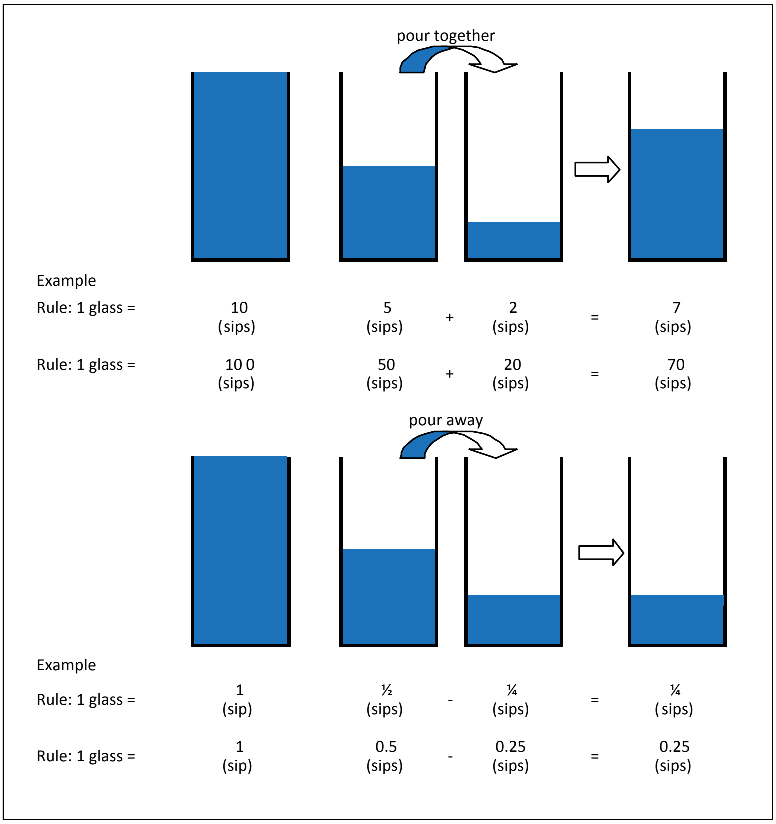


The WIP is child centered and is individually administered and the type of instruction varies. In line with the recommendations of Kroesbergen and Van Luit (2003), the WIP comprises guided self-instruction and direct instruction to build up and enhance basic mathematical facts and problem-solving skills. Drill-training is used to steady arithmetic fact knowledge only when necessary. In addition, there is a great emphasis to include the child actively and increase self-instruction competencies. The trainers conduct the child's process verbally, provide required information, stimulate the verbal reflection of the calculation process, and point out false beliefs if needed. Criticism and the focus on mistakes are avoided. The aim is to enable a child to develop different strategies, and to discover the most effective one.

Furthermore, this procedure should increase self-efficacy and reduce math anxiety which is associated with MLD and low mathematical achievement (e.g., Ashcraft & Faust, 1994; Hopko, Ashcraft, Gute, Ruggiero, & Lewis, 1998).

The organization of the program is semi-hierarchical and semi-standardized (see Figure 1). All children run through every program step and the time spent on each step varies in respect of a child's progress. During steps 0 to 4 children build up basic mathematical skills by using the glasses. At the stage of step 4, the children learn how to connect the pouring process to mathematical concepts. For example, addition is "pouring together" or subtraction resembles "pouring something away" (see Figure 2). Multiplication and division are displayed as a series of addition and subtraction problems respectively. For displaying fractions or decimals, one glass represents "1" (see Figure 2). Steps 4 and 5 are closely connected. Procedural and conceptual knowledge about mathematical operations and their interconnections is systematically taught using direct instruction and self-instruction. Alongside, the children acquire problem-solving strategies and learn to apply their competencies to word-problem tasks. Once a child has built up a stable understanding of numbers up to 100, and has mastered all four mathematical opera-

Figure 2: How to use the water glasses



tions, the "rule" can be changed. Then, a full glass represents 100, 1000 and so on. Thus, even greater ranges of numbers can be displayed by the same material. Step 6 marks the transition to the school curriculum in mathematics.

1.2.3 Evaluation

Müller (2008) examined the effects of the WIP on multiplication competences when applied in school. In one class, the teacher used the WIP to introduce children to multiplication whereas two comparison classes within the same school were taught using the regular approaches. Children who had used the glasses outperformed children who followed the regular curriculum after four weeks of intervention.

Lambert and Spinath (2013) showed that the attendance of the WIP reduced test anxiety, school aversion and psychological problems significantly more compared to children who received private tutoring. This might lead to higher gains regarding mathematical measures. However, to date there is no evaluation of the impact of the WIP for children with MLD on mathematical outcomes, although the program is comparable to other intervention programs which have proved to be effective (e.g., Dowker, 2001, 2007; Fischer-Klein, 2007; Kaufmann et al., 2003). Its organization meets scientific standards and contains fundamental criteria of effective intervention for children with MLD. Due to all of the above mentioned aspects, we therefore assume the WIP to be an effective intervention method which can enhance mathematical skills for children with MLD substantially.

1.3 Private tutoring

Children with MLD who received private tutoring (PT) in mathematics were included as a comparison group in this study. In Germany, 21.7% of elementary school children up to grade four receive private tutoring for mathematics (Bos et al., 2005). There are very few studies which include effects of private tutoring and probably none of the effects on skill improvements for children with MLD. Some studies indicate that private tutoring enhances academic performance in mathematics (e.g., Ireson & Rushforth, 2005), while others found no positive effect on different achievement measures (e.g., Kenny & Faunce, 2004; Smyth, 2008). In a German sample, Mischo and Haag (2002) compared 122 students who attended the grades 5 to 11 at the Gymnasium (highest track of High-School) and received private tutoring with a matched group of students of the same class and performance level without extracurricular assistance. Although there were no differences at pre-test, children who had received private tutoring showed significantly higher school grades at the second measurement point with a high effect size of $d = 0.72$ for mathematics. However, it has to be taken into account that the participants attended the tutoring four times a week with a length of 90 minutes each. This cannot be considered representational for the majority of children attending private tutoring. Guill and Bonsen (2010) examined the mathematical achievement of 6,411 seventh graders of whom 18.2% had had private tutoring during Grade 5 and 6. The authors reported no substantial positive effects on a standardized math test for children who had received private tutoring after controlling for socio-economic status, previous knowledge, IQ and sex compared to children who did not receive tutoring.

Therefore, it is not clear yet, which impact private tutoring has on mathematical achievement or what mechanisms underlie observed improvements. The lack of knowledge is especially true for the impact of private tutoring on children with learning disabilities, even though it can be assumed that there are children with MLD among the students receiving private tutoring. In addition, subject matters, proceedings, and methods used within private tutoring have not been sufficiently taken into scientific focus. Exact contents of private tutoring vary greatly depending on the students and the curriculums characteristics, but according to Kenny and Faunce (2004) some generalizations can still be made.

Tutors activities mostly comprise of giving feedback and hints, teaching and explaining school-related facts, asking questions or choosing tasks (cf. Wittwer, 2008). The content of private tutoring usually focuses on the repetition of school content in mathematics, help with homework and exam preparation, and does not focus on the acquisition of basic mathematical skills. However, this aspect is considered to be most effective for children with severe mathematical difficulties and a basic knowledge of arithmetic operations is indispensable for later mathematic skills (Mercer & Miller, 1992). Therefore, we presume that children with MLD will not substantially improve their mathematical abilities by private tutoring, but require a specialized training which cannot be provided by the traditional approach of tutoring.

1.4 Present study

The aim of the present study was to evaluate the effects of the WIP on the mathematical achievement in a standardized math test, math grades, and parents' ratings. We hypothesized that children with MLD would show a stronger enhancement when supported with the WIP than when receiving private tutoring.

Hypotheses were:

1. Children with mathematical learning disabilities who attended the WIP will show higher gains on *T*-values on a standardized mathematical achievement test than children who received private tutoring.
2. Children with mathematical learning disabilities who attended the WIP are more likely to reach an average level of mathematical achievement (percentile > 29) than children who received private tutoring.

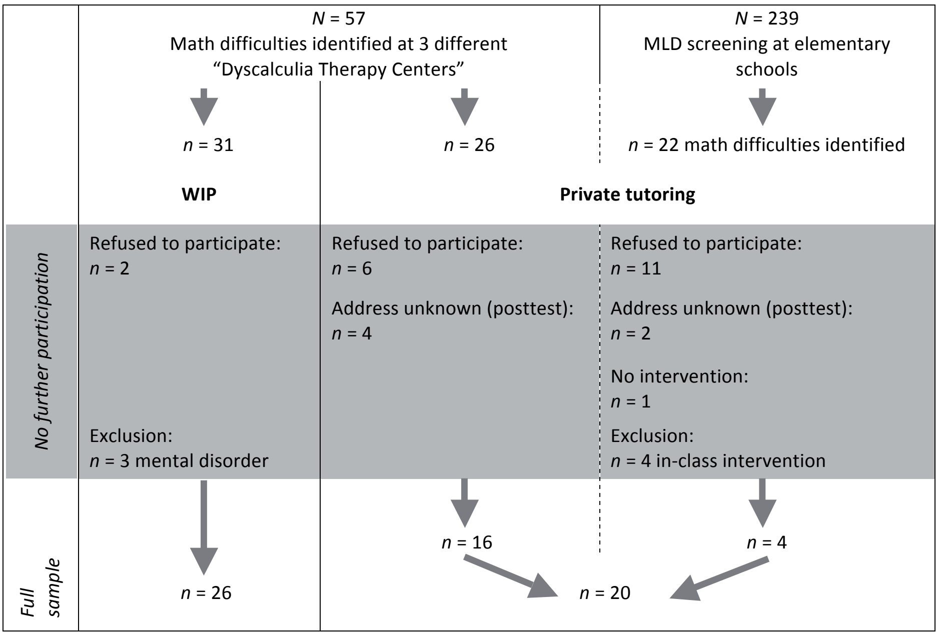
3. Children with MLD who attended the WIP will show higher gains on math grades than children who received private tutoring.
4. Parents whose children attended the WIP will report better mathematical abilities, higher reduction rate of symptoms typical for mathematical learning disabilities, and a higher psychosocial functioning level than parents whose children received private tutoring.

2. Method

2.1 Participants

The data of *N* = 46 German children with MLD were analyzed. Following ICD-10 criteria, children were categorized as having MLD if their performance on a standardized mathematics achievement test was below the 16th percentile (IQ < 80) *or* if their mathematical achievement was 1.5 standard deviations below their IQ-score. All children were Caucasian, and two children were raised bilingual (WIP group: German/French; PT group: German/Turkish). The sampling procedure is presented in Figure 3.

Figure 3: Sampling procedure



Parents had to pay for both types of intervention, but could request financial support from the youth welfare services. Given the program costs and the availability of near-by intervention facilities, it was not possible to assign participants randomly to the two methods of intervention. *N* = 31 parents who had enrolled their children into the WIP at three different "Dyscalculia Therapy Centers" in southern Germany were asked to participate in the study. Two parents refused because of time reasons. Three children were excluded because they had been diagnosed with mental disorders. Thus, the WIP group consisted of *n* = 26 children (16 girls, 10 boys). Math grades were available for *n* = 24 children; one child attended a school without regular report cards and one child had not received school marks at the time of intervention onset. Both children were excluded from analyses addressing math grades. For all other children, all data at all measurement points was available.

The PT group consisted of *n* = 20 children (15 girls, 5 boys) altogether. The first part of this subsample was drawn from children who had participated in the diagnostic process at the Dyscalculia-Therapy-Center Hirschberg but had been enrolled in private tutoring (*n* = 26) by their parents. Of those, four children could not be contacted for posttest measurement, and six parents refused to participate in the study. Therefore, *n* = 16 children of this subsample were included in the study.

Furthermore, *n* = 22 children who had been identified as having MLD in a screening of *N* = 239 elementary school children, were contacted for participation in this study. Of those *n* = 11 parents agreed to further testing of their children. Of those, *n* = 4 children received an in-class intervention, and were therefore excluded in this study. Thus, *n* = 7 children receiving private tutoring were included in this study. During the intervention period, two children moved and could not be contacted for post-test; one child turned out not to have received any interventional program, and was therefore excluded. Therefore, another *n* = 4 children who had participated in the screening were included in the PT group. As a result, the PT group consisted of *n* = 20 children altogether. For all children of the PT group, all data was available for all measurement points.

Table 1 displays the sociodemographic data of both groups at program entry. Groups did not differ in sex distribution, $\chi^2(1) = 0.93$, $p = .33$. In both groups, there was a higher ratio of girls than boys. This is in line with some studies showing a preponderance of girls with MLD (e.g., Geary, Bailey, & Hoard, 2009; Klauer, 1992; Landerl & Moll, 2010; but see e.g., Jordan et al., 2003 and Lewis, Hitch, & Walker, 1994 for different results).

The mean age of the WIP group was 106.27 months (*SD* = 16.70; 8.86 years), whereas the mean age of the PT group was 101.35 months (*SD* = 8.20; 8.45 years). There was no significant group difference for age, $F(1, 44) = 1.46$, $p = .23$. Before intervention onset, most children attended elementary school, ranging from Grade 2 to 4, and three children attended the 6th grade. Three children of the WIP group and four of the PT group had been diagnosed with a co-morbid reading disability; two children in each group were diagnosed with an additional ADHD but mathematic deficits did not vanish under treatment. There was no group differ-

Table 1: Demographic data at program entry by group

WIP (n = 26)		PT (n = 20)	
Numbers		Numbers	
male	10	male	5
female	16	female	15
total	26	total	20
Age (months)		Age (months)	
M	106.27	*M*	101.35
SD	16.70	*SD*	8.20
range	87–149	range	86–119
Grade level		Grade Level	
2nd	15	2nd	13
3rd	4	3rd	5
4th	4	4th	2
5th	0	5th	0
6th	3	6th	0
SES		SES	
M	58.38	*M*	55.40
SD	15.83	*SD*	15.70
range	29–88	range	24–88
Intelligence		Intelligence	
M	94.81	*M*	93.80
SD	8.59	*SD*	10.66
test used		test used	
WISC-III	19	WISC-III	14
WISC-IV	7	WISC-IV	6
Duration of intervention (months)		Duration of intervention (months)	
M	22.46	*M*	23.70
SD	7.80	*SD*	8.39
range	10–38	range	11–37

Note. WIP = Waterglass Intervention Program; PT = Private tutoring; SES = Socio-economic status; WISC-III = Wechsler Intelligence Scale for Children, third edition; WISC-IV = Wechsler Intelligence Scale for Children, fourth edition.

ences in the distribution of co-morbid reading disability, $\chi^2(1) = 0.63$, $p = .68$, or ADHD, $\chi^2(1) = 0.08$, $p = .78$.

IQ was measured using the German versions of the *Wechsler Intelligence Scale for Children* third edition (Tewes, Rossmann, & Schallberger, 2002) und fourth edition (Petermann & Petermann, 2007). A full-scale IQ score was obtained for each participant using all subtests. During the study progress, the fourth edition of the German version of the test was released. In order to receive financial support for the remediation program, children had to undergo a diagnostic process which required the use of the newest edition of the WISC. Therefore, we had to switch to the fourth edition to fulfil these requirements. The additional use of the WISC-III would probably have led to higher IQ-scores due to memory effects since the test versions are very similar on most subtests. 27% of the WIP group and 30% of the PT group were examined with the fourth edition. According to the manual, the correlation between third and fourth edition is $r = .87$. Therefore results are comparable. IQ-scores did not differ between children who had finished the WISC-III or -IV, $F(1, 44) = 0.01$, $p = .94$. The mean IQ-score of the WIP group was 94.81 and 93.80 of the PT group. The small difference of IQ between the groups did not reach a significant level, $F(1, 44) = 0.13$, $p = .72$.

The SES was determined by the International Socio-Economic Index of Occupational Status (ISEI; Ganzeboom, De Graaf, & Treimann, 1992; Ganzeboom & Treiman, 1996). The WIP group showed a mean SES value of 58.38, the PT group of 55.40. Again, we found no significant group difference, $F(1, 44) = 0.40$, $p = .53$. Children of the WIP group attended the program for $M = 22.46$ months ($SD = 7.80$), the PT group for $M = 23.70$ months ($SD = 8.39$), $F(1, 44) = 0.27$, $p = .61$.

2.2 Measures

2.2.1 Math performance

Math ability was measured using the *Schweizer Rechentest* (SR), a series of standardized mathematical achievement tests which assess formal, school-based math skills in elementary school and upper education (SR 1-3, Lobeck & Frei, 1987 and SR 4-6, Lobeck, Frei, & Blöchlinger, 1990). Norms are provided for each class level. The multicomponent tests contain computation problems, open equations (e.g., 14 + __ = 20), word problems, and geometry problems. Each test was submitted according to the curriculum of grade level. According to the manual, correlations with school grades lie between $r = .63$ and .75. Unfortunately, the authors give no information about correlations with other math tests. However, the SR is oriented towards the school curriculum of elementary school and lower high school classes in Germany, and contains a similar spectrum of tasks as do other German math tests. Therefore, the validity of the SR can be assumed to be satisfactory. The retest-reliability on this sample was $r = .77$, coefficient alpha ranged from $\alpha = .82$ to .88.

Additionally, *math grades* were obtained for each child. In Germany, school grades range from 1 to 6 with 1 representing the best possible grade. Children have to achieve a grade of 4 in order to pass a class level. For a better intuitive understanding of the results, grades were recoded so that higher scores represent better achievement.

2.2.2 Parents' ratings

Parents' ratings on changes in *math performance, symptoms* specific for dyscalculia (e.g., finger counting, failure of arithmetic fact retrieval, etc.), and *psychosocial functioning* of their children were assessed with a newly developed questionnaire. It was administered only once after the end of the intervention. Parents were asked to judge the skills of their children retrospectively for the time before intervention onset and for the time at the end of the intervention. In addition, parents of the WIP group were asked to rate their contentment with the intervention program. The questionnaire contained 67 items for the WIP group and 55 items for the PT group. Items were scored on a 5-point scale ranging from strongly agree/very high (0) to strongly disagree/very low (4) with higher scores representing a higher functional level. The scale mathematic performance consists of 7 items (e.g., How good is your child at solving addition problems?), the scale symptoms of 4 items (e.g., The use of finger counting is the only way my child carries out calculation problems.), and the scale psychosocial functioning of 5 items (e.g., The self-esteem of my child is impaired.) for each point of measurement. Coefficient alpha on this sample ranged from α = .77 to .90.

2.3 Procedure

Children of both groups were assessed individually in one or two sessions lasting approximately two hours. The testing was applied directly prior to and after the end of an individual intervention. Within both groups, the duration of the intervention depended on the state of knowledge of the individual child and was not limited. Trainers and parents decided when to stop the intervention in mutual agreement. This was the case when a child seemed to have reached class level or did not show any further progress for several months. In both groups, this decision was not based on any tests and was not influenced. All examiners were trained psychologists or graduate psychology students, and all children attended the MLD intervention program or private tutoring once a week with a length of 50 minutes each. Both types of interventions were administered in a single-subject condition.

The WIP group received a training applying the WIP according to the above mentioned intervention course. Basic mathematical knowledge was systematically taught and gradually linked to the math curriculum of the attended class level (see Figure 1). All instructors were fully trained psychologists or educators.

Children of the PT group received private lessons in math at several tutoring institutions. All instructors were math teachers, educators or specially trained graduate students of educational sciences in mathematics. Private lessons did not follow any special intervention program. The coursework for the children of the PT group depended on the age, school grade, and math curriculum of a child. Teachers did not follow a systematic order. The math textbook of a child was used as the basis of the lessons, and teachers were informed by parents or children about current difficulties. Based on this information, children were mainly doing homework, prepared for exams or repeated the current curriculum or both. Worksheets for repetition were provided for practice. Basic arithmetical knowledge was not systematically taught.

The aim of both intervention conditions was to enable children to catch up to their class level in mathematics. Both groups were meant to have reached grade level by the end of the intervention. Considering this, the standardized math test used in this study should therefore indicate the achievement level of both groups in a comparable way.

2.4 Data analysis

To determine intervention effects, the data were analyzed using 2 (group) x 2 (time) repeated-measures ANOVA, with treatment condition as between-subjects factor. Furthermore, effect sizes were calculated. Group differences of frequency distributions were identified using Pearson Chi^2-test. The exact Fisher test was applied when cell frequencies were below 5.

3. Results

3.1 Pretest differences

The analysis of group differences at the time of intervention onset revealed no significant group differences in the math achievement test, $F(1, 44) = 1.50$, $p = .14$, intelligence score, $F(1, 44) = 0.13$, $p = .72$, or parents' ratings of mathematical performance, $F(1, 43) = 0.34$, $p = .56$, symptoms, $F(1, 43) = 0.19$, $p = .67$, or psychosocial functioning, $F(1, 43) = 0.07$, $p = .79$. However, there was a significant group difference for math grades at intervention onset, $F(1, 42) = 6.98$, $p < .05$, $\eta^2 = .10$, favoring the PT group.

3.2 Mathematical performance

Table 2 presents pre- and posttest means and standard deviations for mathematical achievement measures by intervention condition. As hypothesized, analysis of mathematic test performance revealed a significant main effect of time, $F(1, 44) = 64.81$, $p < .001$, $\eta^2 = .60$, and group, $F(1, 44) = 5.34$, $p < .05$, $\eta^2 = .11$, as well as a significant time x group interaction effect, $F(1, 44) = 21.88$, $p < .001$, $\eta^2 = .33$. The large effect size of the interaction effect was due to the fact that while the groups did not differ at intervention onset (WIP: $M = 32.18$, $SD = 4.81$; PT: $M = 34.24$, $SD = 4.30$), the WIP group reached a T-value ($M = 46.00$, $SD = 6.08$) which lies within the normal achieving range at the end of the intervention, whereas children who received private tutoring increased their mathematical functioning level only slightly (M = 37.90, SD = 7.28), but were still within a low-achieving range.

Table 2: Pre- and posttest measures of mathematical achievement by group

	WIP (n = 26)		PT (n = 20)	
Variables	M	SD	M	SD
Mathematic test score (T-value)				
Pretest	32.18	4.81	34.24	4.30
Posttest	46.00	6.08	37.90***	7.28
Math grades[a]				
Pretest	2.92	0.72	3.43*	0.52
Posttest	4.02	0.68	3.53***	0.72

Note. WIP = Waterglass Intervention Program; PT = Private tutoring.
[a]WIP group n = 24.
*$p < .05$. ***$p < .001$.

To investigate the clinical relevance of the observed improvements with regard to standardized test performance, we further evaluated how many children reached a normal level of mathematical functioning (percentile > 29) by the time they finished the intervention. Children of the WIP group were more likely to reach this level, $\chi^2(1) = 14.30$, $p < .001$. After the end of the intervention, 17 children (65.4%) of the WIP group and 2 children (10%) of the PT group were among the group of normal achieving children. 12 children of the PT group and 3 children of the WIP group showed a percentile < 16 at the end of the intervention and were still diagnosed with MLD. None of the children who showed a performance between percentile 16 and 29 showed an IQ-math discrepancy of more than 1.5 standard deviations. These children were therefore considered as children at-risk.

The analysis of intervention effects on math grades obtained a significant main effect of time, $F(1, 42) = 28.53$, $p < .001$, $\eta^2 = .40$. No significant group effect, $F(1, 42) = 0.001$, $p = .97$, could be found. In line with our third assumption, a significant time x group interaction effect, $F(1, 42) = 19.84$, $p < .001$, was confirmed.[1] The effect size of $\eta^2 = .35$ was large. As shown in Table 2, this effect can be attributed to the fact that children who attended the WIP improved stronger on mathematical school achievement than children who received private tutoring. As mentioned above, before intervention onset the PT group had higher marks (M = 3.43, SD = 0.52) than the WIP group (M = 2.92, SD = 0.72). Whereas children of the PT group hardly improved during intervention course (M = 3.53, SD = 0.72), children of the WIP group improved by more than one grade (M = 4.02, SD = 0.68).

1 Due to the pre-test differences of math grades, we also conducted an ANCOVA with the pre-test math grade as a covariate. In line with the assumption, we found a significant group effect ($F(1, 41) = 10.92$, $p < .01$, $\eta^2 = .21$).

3.3 Parents' ratings

For one pair of parents, the data was incomplete and was therefore excluded from the analysis. Table 3 displays means and standard deviations by group for the three subscales math performance, symptoms, and psychosocial functioning for pre-test and post-test. For the scale of math performance, the main effect of time proved to be significant, $F(1, 43) = 136.61$, $p < .001$, $\eta^2 = .76$. There was no significant group effect, $F(1, 43) = 2.10$, $p = .15$. In accordance with our hypothesis, the analysis revealed a time x group interaction effect, $F(1, 43) = 0.58$, $p < .01$, $\eta^2 = .17$. At program entry, all parents rated their children's mathematical ability as low (WIP: $M = 1.14$, $SD = 0.57$; PT: $M = 1.24$, $SD = 0.48$). In the view of the parents, all children had improved to a medium level until the end of intervention with the WIP groups' ratings ($M = 2.43$, $SD = 0.54$) higher than the PT groups' ratings ($M = 2.00$, $SD = 0.37$).

For the reduction of typical symptoms for MLD a significant time effect, $F(1, 43) = 102.29$, $p < .001$, $\eta^2 = .70$, was revealed. At pre-test, symptoms typical for MLD occurred frequently within the WIP group ($M = 0.84$, $SD = 0.76$) as well as the PT group ($M = 0.75$, $SD = 0.61$). During the intervention course, all children showed fewer symptoms with a mean level at the end of the intervention period (WIP: $M = 2.33$, $SD = 0.68$; PT: $M = 1.80$, $SD = 0.74$). No group effect, $F(1, 43) = 3.38$, $p = .07$, was found. In opposition to our hypothesis, no time x group interaction effect, $F(1, 43) = 3.07$, $p = .09$, was revealed. The WIP group showed no stronger reduction of symptoms than the PT group did during the intervention course.

Similarly, the evaluation of the parents' ratings of the psychosocial functioning of the children showed a significant main effect for time, $F(1, 43) = 76.55$, $p < .001$, $\eta^2 = .64$. The large effect size was due to the strong improvement of both groups. Compared to the time of intervention onset (WIP: $M = 1.41$, $SD = 0.86$; PT: $M = 1.35$, $SD = 0.69$), both groups improved their psychosocial functioning level during the intervention process (WIP: $M = 2.62$, $SD = 0.71$; PT: $M = 2.11$, $SD = 0.70$). In addition, a main group effect, $F(1, 43) = 5.29$, $p < .05$, $\eta^2 = .11$, was found. The medium effect can be ascribed to a slightly higher level of psychosocial function of the WIP group at both measurement points. Yet no time x group interaction effect, $F(1, 43) = 2.43$, $p = .13$, could be obtained, which is not in line with our hypothesis. However, considering the group means and the small sample size, there seems to be a trend for stronger reduction of symptoms and improvement of psychosocial functioning in parents' ratings in the WIP group than in the PT group.

Only parents of the WIP group were asked to judge the success and their contentment with the intervention. Intervention success was rated as good ($M = 3.07$, $SD = 0.69$) and parents were satisfied with the program ($M = 2.81$, $SD = 0.90$).

Table 3: Pre- and posttest measures for parents' ratings by group

	WIP (n = 26)		PT (n = 20)	
Variables	*M*	*SD*	*M*	*SD*
Math performance				
Pretest	1.14	0.57	1.24	0.48
Posttest	2.43	0.54	2.00***	0.37
Symptoms				
Pretest	0.84	0.76	0.75	0.61
Posttest	2.33	0.68	1.80	0.74
Psychosocial functioning				
Pretest	1.41	0.86	1.35	0.69
Posttest	2.62	0.71	2.11	0.70

Note. WIP = Waterglass Intervention Program; PT = Private tutoring.
***$p < .001$.

4. Discussion

This study evaluated the intervention effects of the WIP (Schlotmann, 2004) which is a numeracy recovery training for children with MLD. These were compared to a group of children with MLD who received private tutoring (PT) during the intervention course. Children attended the intervention facilities either for the program or tutoring for an average of almost two years. Results demonstrate the efficacy of the WIP in the remediation of children with MLD. As expected, private tutoring could not substantially improve mathematical skills of most low-achieving children. Effect sizes were high for group intervention effects. Relative to the PT group, children who attended the WIP increased their test-score in a standardized math test to a higher degree. On average, the WIP group reached the level of normal achieving children in the same grade. Children in the PT group showed an improvement in their mathematical skills as well, but the mean *T*-value remained at an interval which can be considered to be low-achieving. The results are consistent with previous studies that have shown that children with MLD can improve their mathematical skills if they undergo special training (e.g., Dowker, 2001; Fuchs et al., 2009; Kaufmann et al., 2003).

Most intervention studies have taken school- and teacher-based interventions for children with MLD into account. The programs were applied in a relatively short amount of time during school hours and usually focused on the improvement of specific mathematical skills, but not on the normalization of an overall mathematical achievement. Hence, only the addressed aspects of mathematics were investigated. The present study concentrated on a long-term program which is applied outside of the school setting. The WIP claims to enable children with MLD to catch up on mathematical skills of their age group, as is the intention of private tutoring. Therefore, intervention outcomes were analyzed for clinical significance. Children who had reached a percentile > 29 were classified as average achieving in mathematics. Two-thirds of the WIP group children managed to do so. This was true for only 10% of the PT group. At the same time 7.7% of the WIP group but almost two-thirds of the PT group remained below the 15th percentile.

These findings were reflected in the gains in math grades. Whereas children in the PT group showed almost no grade improvement, children of the WIP group improved mathematics school achievement by more than one grade. Thus, children who attended the WIP were able to transfer ability gains to school mathematics.

Parents' ratings of the improvements of their children were included in the data analysis. Since both, achievement on the math test and in math grades might be negatively affected by parameters such as math-anxiety (e.g., Ashcraft & Kirk, 2001; Nelson & Harwood, 2011), parents might provide further indication of the ability improvements of their children. Furthermore, the parents' ratings allowed us to retrieve additional information about the psychosocial functioning of the participants as well as the occurrence of typical symptoms of MLD such as finger counting, a lack of arithmetic fact retrieval or conceptual understanding. There were no pre-test differences in performance or function ratings between the conducted groups. Intervention effects over time were significant for both groups. However, parents whose children attended the WIP claimed a higher level of mathematical ability for their children by the end of the intervention than parents whose children had received private instruction. This also indicates that in the view of the participants' parents, children who attended the WIP were more successful in enhancing their mathematical skill, even though the effect was much smaller than for objective data. No significant differences between groups were found for symptoms and psychosocial functioning. Both groups reduced symptoms of MLD and psychosocial impairment significantly during the intervention. Yet means indicate a trend for better outcomes favouring the WIP group. While interpreting these results it has to be taken into account that ratings for the intervention onset were retrieved retrospectively. Parents might have judged their children's functioning lower for this point in time. Moreover, all children improved their arithmetic skills. This might have led to a positive rating in general since parents did not have a reference group of other children with MLD. Considering the high degree of mathematical impairment at program entry, parents might have also concentrated on small gains. This could especially be true for parents of the PT group. Given the costs of the programs, the overestimation of achievement gains might have reduced cognitive dissonance (Aronson, 1992), since parents expected at least some results for the money spent, even if no substantial improvement could be objectively observed. Whereas parents of the WIP group might have judged the improvements of their children more realistically since most children indeed caught up with their class-level.

Above, WIP group parents thought the intervention to be successful and were satisfied with the program's organization and course. Parents of the PT group did not rate intervention success.

4.1 Limitations of the present study

The present study contains several noteworthy limitations. First, the sample size was rather small which results in a reduction of test power. Second, children could not be randomly assigned to an intervention condition due to financial and organizational reasons, and it was not possible to include an untreated control group since the exclusion from remediation for the duration of almost two years does not meet ethical demands. Thus, systematic differences between conditions cannot be ruled out. At the time of intervention onset, the PT group had significantly higher math grades compared to the WIP group. This might have affected the motivation to improve; children of the WIP group could have had a higher ambition to obtain better grades due to the very low achievement level whereas the PT group was under lower pressure. However, when considering that early grades are an integral predictor of later achievement, and that children with MLD usually do not catch up with their classmates (e.g., Jordan et al., 2003; Krajewski & Schneider, 2009; Shalev, Manor, Auerbach, & Gross-Tsur, 1998), this explanation does not seem very likely. Also, even though the math grade difference reached a significant level, it can be questioned whether this difference of half a grade practically made a difference in the perception of the children regarding their ability level.

In addition, math grade differences could have had the function of a selection criterion, with children of the PT group having a slightly higher mathematical functioning level. Parents of the WIP group might have experienced a higher level of psychological strain so that they might have been more likely to accept higher financial and time costs. The costs of private tutoring are usually below the costs of the WIP. However, the groups did not differ on the standardized math test or on parents' ratings of the arithmetic abilities of their children as well as SES, which could have had an impact on the choice of intervention type. In addition, the participants of the two intervention conditions did not differ on any other measure, such as age, IQ, duration of intervention, sex, comorbid reading disability, ADHD, and parents' ratings on symptoms and psychosocial functioning at the time of program entry. Even though further group differences cannot be ruled out completely, it is likely that intervention conditions accounted for group effects, and results can still be interpreted in favour of the WIP group.

A third related limitation concerns the generalizability of the results. Due to several restrictions, the findings have to be interpreted with some caution in respect of this aspect. Many more girls than boys attended the intervention (2.1:1). As mentioned above, this findings stands in line with previous research (e.g., Geary et al., 2009; Klauer, 1992; Landerl & Moll, 2010). However, epidemiological studies also reported an equal ratio of sexes (e.g., Gross-Tsur et al., 1996; Lewis, Hitch,

& Walker, 1994). Since this issue has not been conclusively resolved, it is not possible to rule out that the sample was skewed regarding gender. Further studies have to explore whether girls and boys benefit from different intervention methods and if different ratios influence intervention outcome measures. To date, there are no indications that this is the case. Still, in this study, the proportion of girls seems to be slightly higher than in the studies reporting a higher incidence of MLD in girls. This might be due to the fact that boys are more likely to suffer from reading disabilities or ADHD. Because of high comorbid rates it is possible that boys are enrolled in other remediation programs first, and are less likely to receive intervention for MLD.

Another aspect restricting the generalizability of the findings concerns the SES which lay above the expected mean of 49 for OECD countries in both groups. Both the WIP and private tutoring require high expenditures by parents. Therefore, results might not be representative for all children with MLD but only for those who belong to middle or high income families. However, parents could apply for financial support from the German youth welfare services. This is especially true for parents whose children attended the WIP. So children with a low SES are able to and did attend the interventions.

This leads to the fourth limitation. All children attended commercial facilities; therefore, the intervention was not carried out under fully controlled conditions. Due to the individualized procedures of both interventions, it was not possible to gain quantitative data about treatment fidelity or to determine an equal intervention timeframe for all children. Still, the qualitative review of reports revealed that all interventions were typical for either the WIP or private tutoring. Regarding the duration of interventions, the groups did not differ in mean duration or range; therefore, results can be compared between groups. However, we cannot completely rule out that teacher-child interactions could have been different between groups and could have affected intervention outcomes.

One could argue that all intervention studies should be conducted under fully controlled conditions, especially concerning random assignment. However, in Germany as well as in other countries, these kinds of facilities are an integral part of learning disability remediation. Evaluating these facilities independently has two benefits. First, it guarantees that children receive a well-founded and effective treatment; second, this course of action might reveal new insights about different types of intervention approaches and might substantially contribute to the knowledge about the remediation of children with MLD. Commercial facilities depend on having a good reputation and might therefore develop new ideas which should then be regarded in scientific research. Excluding scientific evaluations of programs having methodological difficulties might lead to an oversight of effective help for children with MLD. Still, it must be the ambition to give access to numeracy recovery programs to all children and to evaluate those under controlled conditions and having bigger sample sizes.

The fifth limitation concerns the choice of math test. The Schweizer Rechentest does not provide updated norms and was designed for German-speaking Swiss children. Some authors noted that the level of difficulty is higher than on other German curriculum-based tests. However, this makes the reported results even more encouraging because one would expect better results on other standardized math tests. In this study, test versions were chosen considering the requirements of grade level. So we expected the results to represent the participants' mathematical functioning level. We decided to apply this test series for two major reasons. First, this math test was the only one available for measuring curriculum based mathematical skills of elementary as well as high-school students with a stable level of difficulty. Therefore, the application of this test assured that we could include students who switched to higher education during the intervention course, and that the results were not due to a change in the type of tests. The second reason for choosing the Schweizer Rechentest was due to additional diagnostic processes at other psychological institutions, which children had to undergo. For some children, schools or intervention facilities required professional reports of accredited institutions. Therefore, we decided to use a measure for mathematical ability which is rarely used within official diagnostic procedures in order to rule out the possibility that ability improvements were due to test familiarity.

Finally, it has to be mentioned that we cannot make a statement about the stability of the improvements shown by the children who attended the WIP or whether the WIP produces better results than other programs which address all domains of mathematics.

4.2 Implications of findings and future research

Although the present study contains several limitations, its results are very encouraging and provide an indication that a lot of children will benefit from the WIP. In contrast, private tutoring does not seem to be sufficient for the remediation of the majority of children with MLD. Considering the long-term consequences which children with MLD will possibly face, these results confirm the assumption that children with MLD are able to catch up to their grade level when given adequate support. Further studies are needed to verify the stability of improvements attained by the WIP and it has to be evaluated whether the efficacy of the WIP is equal to or even higher than that of other intervention programs. Moreover, impact factors which influence intervention outcome need to be assessed. When conducting further research, the manipulative material used should be taken into focus. It can be assumed that the choice of material might have an impact on intervention outcomes. It is necessary to examine if the use of a continuous material such as water produces better outcomes than countable manipulatives as stated by Schlotmann (2004).

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Schülerinnen und Schüler mit niedrigem familiären sozioökonomischen Status und/oder Sprachdefiziten in Deutsch erzielen überdurchnittlich häufig schlechtere Schulleistungen in Lesen, Mathematik und Rechtschreiben. Diese Studie schließt an Forschungen zu sozialen Disparitäten beim Schulerfolg an. Es werden jedoch Merkmale von sozial und ökonomisch benachteiligten Kindern untersucht, die erwartungswidrig dennoch erfolgreich in der Schule sind. Dabei werden Zusammenhänge wie Familienstruktur, kognitive Fähigkeiten der Schüler, kulturelles und soziales Kapital der Familie sowie Bildungsaspirationen der Eltern in den Blick genommen.