The Effects of a Multicomponent Motivational Intervention on Math Performance of Elementary School Students With Learning Disabilities

Matthias Grünke
Jennifer Karnes
Susanne Hisgen
University of Cologne, Germany

The purpose of this single case study was to evaluate the effects of a multicomponent motivational intervention that consisted of explicit timing, immediate feedback through self- scoring, goal setting, and positive reinforcement on the arithmetical skills of three third graders with learning disabilities. An ABA reversal multiple-baseline across-participants design was applied to establish a functional relationship between the intervention and the expected outcome. Immediately after the motivational system was implemented, the participants solved a higher number of tasks. The effect ended abruptly once the treatment was terminated. Results show that even for struggling students with learning disabilities, motivation to solve math tasks can be notably increased with relatively little effort. The paper ends with a discussion of current literature and the experiment's limitations, as well as the practical use of the findings.

***Keywords:* nonverbal learning disabilities in written language, multicomponent motivational system, explicit timing, self-scoring, positive reinforcement**

Introduction

Basic mathematical computational competences are absolutely essential for many areas of children's current and future life (Casey, McLaughlin, Weber, & Everson, 2003; Haring, Lovitt, Eaton, & Hansen, 1978; Lloyd, 1978). Capabilities to manage time properly, to handle financial matters, or to purchase daily goods are just a few examples of how basic mathematical skills are used in one's daily routine (Brown & Snell, 2000).

Sufficient arithmetic fluency is an essential, yet not sufficient, prerequisite for being able to solve complex mathematical problems. One must be in a position to retrieve math facts quickly and effortlessly to attend to more sophisticated tasks. Otherwise, one's working memory might be overstrained and not in the place to meet the requirements posed by a particular intricate problem. The risk of getting stuck in the use of counting strategies and the overall failure

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frequency increase for children who lack these capacities (Miller & Heward, 1992; Pieper, 1983). Finger-counting strategies are inadequate when multiplication and division tasks or even more complex math problems have to be solved (Casey et al., 2003; Silbert, Carnine, & Stein, 1990; Stein, Silbert, & Carnine, 1997). This emphasizes the relevance of promoting arithmetic facts in struggling children.

Regardless of the considerable variance in the numerical development in children, most of them arrive at the same "place" academically by the end of their elementary education and possess sufficient math skills to successfully tackle formidable word problems. However, a considerable share of up to a quarter do not acquire basic arithmetic competencies before moving on to secondary school (Salend, 1998; Wendt et al., 2016; Wood, 1992).

Students with a learning disability are especially at risk for developing severe math difficulties (Goldman, Pellegrino, & Mertz, 1988). They usually experience serious problems understanding number-related concepts or using symbols or functions needed for calculating (Swanson, Olide, & Kong, 2018). Fortunately, there are a number of effective interventions that can help these children and adolescents to meaningfully improve in their academic abilities (Dennis, Sharp, & Chovanes, 2016; Jitendra, Lein, & Im, 2018; Stevens, Rodgers, & Powell, 2018). Approaches aimed at enhancing math fact fluency involve daily drills and practice (Anthony, Rinaldi, Hern, & McLaughlin, 1997), flash cards (Ashbaugh & McLaughlin, 1997), Say All Facts One Minute Each Day Shuffled (Eshleman, 1985; McDade, Austin, & Olander, 1985), and daily charting (Abba & McLaughlin, 1995; Casey et al., 2003; Lindsley, 1991; West, Young, & Spooner, 1990).

One technique that has received little attention in recent years, but appears to be very promising in this context, is called explicit timing (Van Houten & Thompson, 1976). It is a procedure that alerts students to a time limit while they are completing an assignment. The mere fact that learners are made aware of how long they have been working on a task and how long there is still to go seems to help them focus on a given challenge and perform better (Grays, Rhymer, & Swartzmiller, 2017). Explicit timing is often combined with immediate feedback through self-scoring (Gross & Duhon, 2013), goal setting (Codding, Lewandowski, & Eckert, 2005), and operant conditioning (Freeland & Noell, 1999). Using these techniques conjointly appears to accelerate the effects of explicit timing. When applying immediate feedback through self-scoring, students keep track of their performance at the end of each learning session (Light, McKeachie, & Lin, 1988). They set a goal to not fade next time but to beat their own high score. Oftentimes, the respective high score is prominently displayed on a poster on the wall of the classroom or on the front of a student's workbook. The teacher acknowledges the children's effort and accomplishments by providing rewards in the form of vouchers, toys, sweets, and the like (Archer & Hughes, 2011; Prater, 2018).

Explicit timing in combination with immediate feedback through self-scoring, goal setting, displaying high scores, and operant conditioning has been shown to be effective in a variety of different contexts, such as reading (e.g., Grünke, Karnes, & Hisgen, 2019; McDaniel, Jolivette & Ennis, 2013) and writing instruction (e.g., Grünke, Knaak, & Hisgen, 2018; Grünke, Sperling, & Burke, 2017). However, such a multicomponent motivational system has not been evaluated very often in connection with enhancing students' math fact fluency. A number of researchers have reviewed the benefits of explicit timing on arithmetic skills in isolation (e.g., Duhon, House, Hastings, Poncy, & Solomon, 2015; Grays et al., 2017; Rhymer, Henington, Skinner, & Looby, 1999), but not in connection with accompanying approaches aimed at additionally boosting motivation and performance.

Thus, the purpose of the present study was to examine the efficacy of a multicomponent motivational system consisting of explicit timing, immediate feedback through self-scoring, goal setting and displaying high scores, and positive reinforcement on the math fact fluency of learning-disabled third graders. We expected that the intervention would elicit an immediate boost in performance, which would disappear as soon as the treatment ended.

Method

Participants and Setting

Participants included three third graders (Anna, Ben, and Colin; names changed for anonymity) from an inclusive elementary school in a major city in Northrhein-Westfalia (Germany). All of them were referred to the first author by their main teacher due to their low motivation to engage in math activities. The school and the three authors of this paper have been cooperating for a number of years, trying to jointly find ways to better support especially challenging students to achieve basic reading, writing, and math proficiency by the end of their elementary education. To be eligible for this experiment, children had to understand the concepts of two-digit addition and two-digit subtraction but perform within the last 20% of their age bracket in a standardized math test. Furthermore, despite their low math motivation, they had to be willing to take part in the study.

To select suitable participants for this experiment, we conducted the subtests "Addition" and "Subtraction" of the Heidelberg Math Test 1–4 (HRT 1–4) by Haffner, Baro, Parzer, and Resch (2005) with the whole class and asked each student to finish a DIN-A-4 worksheet containing 10 two-digit addition and 10 two-digit subtraction problems, taken from Klauer (1994). It was arranged in a way that addition and subtraction items alternated. The children were granted as much time as they needed to complete the worksheet. We considered the prerequisite for basic comprehension of addition and subtraction concepts to be fulfilled if the students were able to solve at least 80% of the problems.

One girl and two boys were identified as eligible for the study. All of them had been diagnosed with a learning disability by a specialist. The first participant was 10-year-old Anna. She was born to German parents and spoke German at home. According to her main teacher, she was generally eager to learn but had developed a very negative math self-concept. Anna had trouble working on basic arithmetic problems for longer than 5 minutes. She usually became tired and halfhearted after a very short time, subsequently engaging in daydreaming. According to the HRT-4, Anna achieved a percentile of 4 in her ability to correctly solve addition problems, as well as in her ability to solve subtraction problems. However, she ended up with 85% correctly solved items on the worksheet. Nine-year-old Ben (male) was the second participant. Like Anna, Ben did not have an immigrant background. His main teacher characterized him as a boy who frequently needed breaks due to his short attention span. Ben's percentile in the HRT-4 addition subtest was 17, and his subtraction percentile was 4. He performed well on the worksheet, solving 87% of problems correctly. The third and last participant was 10-year-old Colin. His teacher reported that he stood out due to his tendency to get distracted. She ranked his potential far higher than his actual performance. Colin achieved a percentile of 2 in the HRT-4 addition subtest and 1 in the subtraction subtest. However, he was able to solve all items on the worksheet correctly.

Interventionist

A female graduate student of special education executed the study together with the treatment. Because of her side job as a private tutor and her practical school training as part of several internships, she was used to working with low-performing elementary school children. During four 45-minute meetings, the interventionist received extensive briefings by the first author on how to conduct the experiment. We used a checklist that contained every central feature of the assessment and the treatment that she was supposed to adhere to. The interventionist and the first author stayed in contact via e-mail each week of the experiment to make sure that everything went according to plan.

Dependent Variables and Measurement

We used the number of correctly solved math items (SMIs) on 15 different worksheets as the dependent variable. These materials were arranged like the ones we used to appraise the comprehension of basic addition and subtraction concepts (see above). Each worksheet contained 20 two-digit addition and 20 two-digit subtraction problems. Again, the items were taken from Klauer (1994), and the types of tasks alternated. The time limit was set to 10 minutes.

On each day of the study, the participants were handed one of the 15 sheets in random order. However, it was ensured that they were never given the same set of items twice.

Experimental Design and Procedures

An ABA plan was implemented to evaluate the effects of the intervention with 15 daily probes. In this design, a baseline period (A1) is followed by a treatment phase (B). To test if the effects return to the baseline without intervention, the treatment is then withdrawn (A2; Riley-Tillman & Burns, 2009). To increase the internal validity of the study (see Dugard, File, & Todman, 2012; Tate et al., 2016), the beginning and the end of the intervention were determined randomly for every case within the constraint that each phase had to consist of at least three measurements. Thus, the B phase could have started any time between the 4th and the 9th and ended anywhere between the 7th and 12th probe. A random drawing of all possible options for each participant resulted in an arrangement whereby the treatment began for Anna after the 5th and ceased after the 10th; for Ben, it started after the 3rd and finished after the 8th; and for Colin, it launched after the 6th and concluded after the 11th measurement.

During baseline conditions (A1 and A2), the children were individually taken out of their class during the second period each day to a resource room of the school and seated at a table. The order in which they accompanied the interventionist varied. Once the participants had settled, the graduate student asked them to work on the math problems and to try as hard as they could to achieve the best results they were capable of. She measured the time coveredly with a wrist watch and asked them to stop as soon as 10 minutes were up. At the end of each session, Anna, Ben, and Colin filed their worksheets in a plastic folder. No feedback was given whatsoever.

During the B phase, the interventionist placed a 7x7-inch timer on the table for the children to see. She explained to them that they had exactly 10 minutes to work on the problems as quickly and assiduously as possible. In addition, she presented them with a line diagram, depicting their performance during all previous baseline and intervention sessions. The interventionist pointed out that the children had already delivered respectable results and encouraged them to keep trying hard. Each folder had a cellophane window on the front cover. With the first B-phase session, an index card with the hitherto existing SMI high score was placed in this window for the participants to see. After the interventionist introduced the timer, the line diagrams, and the index card, she set the timer to 10 minutes and the children worked on the math problems until the time was up. Subsequently, the student, with the assistance of the interventionist, counted the number of SMIs and recorded it on the line diagram. If the high score was beaten, the card in the cellophane window was replaced. Finally, the worksheet was filed in the folder. Every time the children reached at least their previous high scores, the interventionist rewarded them with a sticker.

Results

Figure 1 shows the number of math problems correctly solved by each participant in 10 minutes.

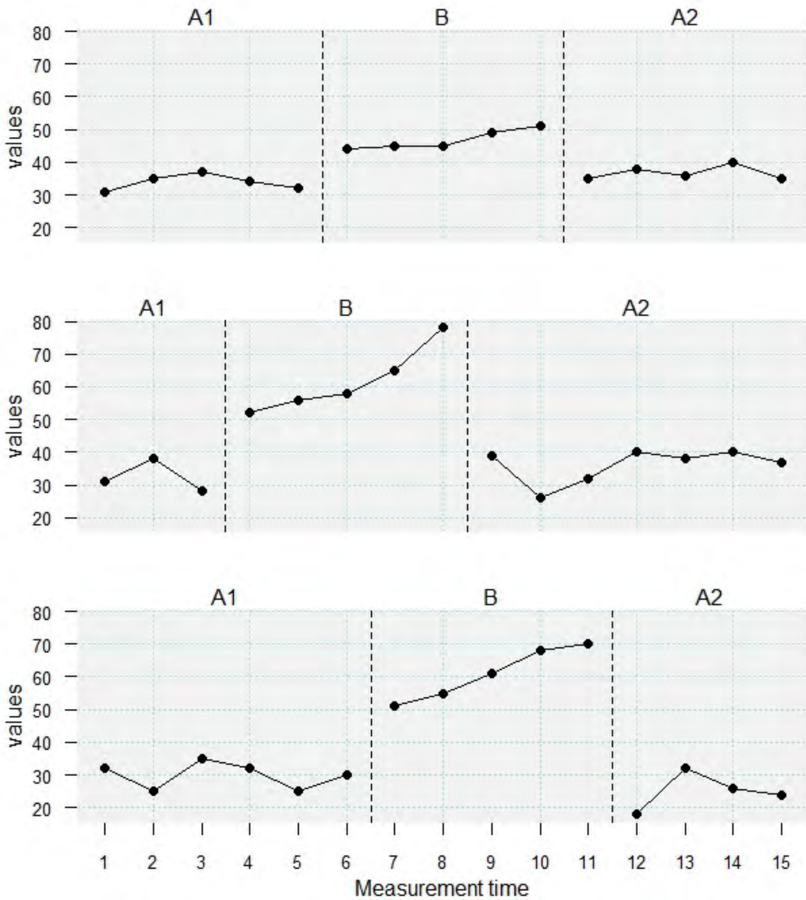

Figure 1. **Number of SMIs for Anna, Ben, and Colin in the three phases.**

Anna was in the baseline condition (A1) for 5 days and averaged 33.80 SMIs (range = 31–37). The measurements during this phase can be considered relatively stable. The intervention (B) was introduced on the sixth day, coinciding with an immediate achievement gain. In fact, Anna's mean SMI improved by 38.46% to 46.80 (range = 44–51). On Days 7 and 8, she reached 45 SMIs each time. Apart from that, each subsequent score in the B phase always exceeded the previous one. The return to baseline (A2) led to an immediate change in level:

The average SMI subsided by 21.37% to 36.80 (range = 35–40). Calculating five of the most common non-overlap effect sizes comparing phases A1 and A2 to phase B—percentage of non-overlapping data (PND), percentage of data exceeding the median (PEM), percentage of data exceeding the median trend (PEM-T), non-overlap of all pairs (NAP), and percentage of all non-overlapping data (PAND; Alresheed, Hott, & Bano, 2013)—resulted every time in the highest outcome of 100%.

Ben was in the baseline condition for only three measurements and averaged 32.33 SMIs (28–38). With the start of the intervention, his performance rose from 28 on Day 3 to 52 on Day 4. He continuously improved during the B phase until he reached 78 on Day 8. His mean value for SMIs during the intervention equaled 61.80 (range = 52–78), which corresponded with a 91.15% increase. After the treatment was suspended, his average achievement dropped by 41.75% to 36.00 (range = 26–40). Like in the case of Anna, Ben's non-overlap effect sizes (PND, PEM, PEM-T, NAP, and PAND) all equaled the maximum value.

During six days of the baseline condition, Colin averaged 29.83 (range = 25–35) with relatively stable data. Introduction of the intervention was accompanied by a performance gain in SMIs from 30 on Day 6 to 51 on Day 7. The mean value for the measurements during the B phase was 61.00 (range = 51–70), which parallels an impressive 104.49% increase. Again, Colin demonstrated a consistent boost in SMIs over the course of the treatment. The grave decline in output between his last measurement during phase B (70) and his first one in phase A2 (18) is remarkable. His average performance after his return to baseline conditions equaled 25.00 (18–32), which reflects a 59.02% decrease. All effect sizes (PND, PEM, PEM-T, NAP, and PAND) reached a peak outcome of 100%.

To analyze the conjoint effect of all cases, we conducted a randomization test for ABA multiple baseline designs (Dugard et al., 2012) using the SCAN package for R by Wilbert (2018). This statistical technique is robust against serial dependent data and provides probability values for generalizing the results (Grünke, Boon, & Burke, 2015). The randomization test was set up in accordance with the design, allowing for at least three measurements per phase. As expected, the mean differences between the phases did reach statistical significance ($p < .001$).

Finally, we carried out a piecewise regression analysis for each participant (see Huitema & McKean, 2000), again applying the SCAN package by Wilbert (2018). The results are depicted in Table 1.

Table 1. ***Piecewise Regression Model for Number of SMIs***

	b	*SE*	*t*	*p*	R^2
	Anna				
Intercept	33.50	2.36	14.21	>.01**	
Trend	0.10	0.71	0.14	0.89	0.00
Level Phase B	7.40	2.93	2.52	.03*	0.06
Level Phase A2	-14.20	2.93	-4.84	>.01**	0.22
Slope B	1.70	1.01	1.69	0.13	0.03
Slope A2	-1.60	1.01	-1.59	0.15	0.02
	Ben				
Intercept	35.33	7.67	4.61	>.01**	
Trend	-1.50	3.55	-0.42	.68	0.00
Level Phase B	12.67	6.98	1.81	.10	0.03
Level Phase A2	-42.00	5.76	-7.30	>.01**	0.43
Slope Phase B	7.60	3.89	1.95	.08	0.03
Slope Phase A2	-5.10	1.85	-2.76	.02*	0.06
	Colin				
Intercept	31.13	4.15	7.50	>.01**	
Trend	-0.37	1.07	-0.35	.74	0.00
Level Phase B	16.80	5.69	2.95	.02*	0.04
Level Phase A2	-49.20	6.47	-7.61	>.01**	0.28
Slope Phase B	5.47	1.77	3.09	>.01**	0.05
Slope Phase A2	-3.90	2.44	-1.60	.15	0.01

Note: * Significant at the 5% level; ** significant at the 1% level.

As the findings indicate, Anna and Colin demonstrated a significant level effect from phase A1 to phase B. However, only in the case of Colin did the changes in slope fall below a *p*-level of 5% upon the onset of the intervention. As the treatment came to a halt, all three children showed a significant drop in level. However, comparing phases B and A2, only Ben's slope turned out to be different, with a probability of less than 5%.

Discussion

Main Findings

In the present study, we examined the effects of a multicomponent motivational intervention, consisting of explicit timing, immediate feedback through self-scoring, goal setting (and displaying high scores), and operant conditioning on the math fact fluency of three third graders with learning disabilities. The results show that the number of SMIs was greatly increased by the treatment. Visual inspection, effect size indices, a randomization test, and piecewise regression analyses all suggest that the intervention was very effective in increasing participants' performance. The data indicate that the math fact fluency of learning-disabled third graders can be significantly improved even by very simple means. In the A phases, achievement was considerably lower for all students than during the B phase. From this, it can be concluded that the target behavior was not transferred to situations in which the intervention was not implemented. Overall, the results of the present study confirm the findings from the previous research works cited above.

Critical Reflections

Despite these positive results, some limitations of the experiment need to be considered. As with any single-case analysis, the findings cannot be generalized due to the small sample size. In addition, it is critical to note that only a relatively short period of time was available for executing the study. The internal validity of the single-case analysis could have been increased by including a larger number of measurement times. A second B phase would have served the same purpose. Nonetheless, an ABA reversal design, as used in the present study, is already considered very meaningful when trying to quarry valid findings (Riley-Tillman & Bruns, 2009).

Another point of criticism is that in this work, only scarce information was provided about the participants. No details were given on the individual backgrounds of the students (such as a description of their previous school career or their IQ). This lack of specific information makes replicating the study difficult.

In addition, the results could only be determined based on the effects of the combination of different motivational methods. To what extent which element of the approach was responsible for the treatment effects cannot be specified. However, this would have been necessary to be able to appraise the benefits of the different components of the motivational system on which this study focused.

It should also be noted that setting a time limit is not necessarily helpful with all kinds of tasks and all kinds of students. What might be useful in quickly retrieving math fact fluency might not be at all advantageous when solving elaborate word problems. Furthermore, some learners might not take too well to time limits. It could elicit performance pressure, causing stress, uptightness, or even anxiety (Rhymer et al., 1999). Thus, it might be appropriate to provide high-strung or jumpy students with interventions other than explicit timing.

Practical Implications

Despite the described limitations, the present study provides valuable insights into how learning-disabled students with problems in retrieving basic math facts quickly can be easily motivated to engage in arithmetic problems and how fluency in this respect can be increased. The results show that a multicomponent motivational intervention has the potential to have a tremendous positive impact on the performance of elementary school children and their willingness to get involved in tasks that they previously avoided.

Girls and boys with learning disabilities frequently demonstrate severe difficulties in mathematics. It is often extremely challenging for them to live up to even very basic expectations in this area. Initial problems accumulate over time and lead to regular experiences of failure, a negative academic self-concept, and feelings of aversion toward school in general (Gottfried & Kirksey, 2017). To interrupt this negative spiral, it is important to enable the affected students to experience self-efficacy. The approach described in this study offers a chance to do just that. Through the presentation of each solved task, the children are shown how much they have already accomplished and how much they have improved. Displaying the high scores and providing frequent praise contribute to students' beliefs of having successfully mastered ambitious tasks. Of course, executing a simple intervention for a couple of days is not enough to make up for many experiences of failure that some students might have accumulated. Nevertheless, the approach can be considered a serviceable means to reduce fear of failure and build motivation.

Notwithstanding the smallness of the contribution that this study is able to make to the body of research in the field of fostering basic math skills, it has demonstrated that it is undoubtedly possible to enhance arithmetic performance with rather plain means in a very effective way. All techniques applied in this experiment—explicit timing, immediate feedback through self-scoring, goal setting, and operant conditioning—are extremely simple to implement and require very little time and effort. In addition, the process is so frugal that it does not require in-service training for teachers before they can incorporate the motivational system into their daily teaching routine. Thus, the intervention can be considered very user friendly under conditions of everyday life at school. Especially in view of increased heterogeneity among students in an era of inclusion, this aspect is of particular importance. The majority of teachers simply do not have the ways and means to constantly attend to the needs of every child. Hence, simple techniques like the multicomponent motivational system described in this paper are needed more than ever.

Conclusions

The present single-case experiment has shown that basic arithmetic fact fluency can be easily enhanced with very little means. Insights such as the ones based on the findings of this study have the potential to prepare learning-disabled or otherwise struggling students for the demands they face during math instruction. This could contribute to combatting the problem that many children leave elementary school without meeting fundamental numeracy skills. Equipping them with solid abilities to perform basic math operations would certainly help them when they have to successfully master the transition from elementary to secondary school. Of course, there are still some significant blind spots in research concerning the efficacy of multicomponent motivational systems to promote numeracy skills in children. Nonetheless, this study can be seen as at least a small contribution to shed more light on the benefits that an intervention like the one described in this paper can have on learning-disabled or otherwise low-performing children.

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Authors' Note

Correspondence concerning this article should be addressed to: Matthias Grünke, Ph.D., Department of Special Education & Rehabilitation, University of Cologne, Klosterstr. 79b, 50931 Cologne, Northrhine-Westfalia, Germany, Phone: 0049-221-4705547, Email: matthias.gruenke@uni-koeln.de.