Using Count-Bys to Promote Multiplication Fact Acquisition for a Student with Mild Cognitive Delays: A Case Report

Matthias Grünke

University of Cologne, Germany

Kim Calder Stegemann

Thompson Rivers University, Canada

Contact Information:

Matthias Grünke, Ed.D.

Department of Special Education & Rehabilitation

University of Cologne

Klosterstr. 79b

Cologne, Northrhine-Westfalia, 50931

Germany

Phone: 0049-221-4705547

E-mail: matthias.gruenke@uni-koeln.de

**Abstract**

The purpose of this study was to evaluate the efficacy of a simple technique (Count-Bys) to enhance multiplication facts fluency in struggling learners. A single-case multiple baseline design across three fact sets was applied. The subject was a 12-year old boy with mild cognitive delays, who demonstrated adequate addition skills, but was mostly unable to perform multiplications. At the end of about two weeks of practicing the Count-By strategy with three fact sets, the boy had reached mastery as measured by the number of accurately written digits within five minutes in response to a worksheet containing 30 multiplication problems. Follow-up data taken during a period of two weeks upon termination of the intervention indicated that the student nearly maintained mastery levels across all fact sets. The benefits of using Count-Bys in a peer tutorial setting in order to enlarge teacher‘s opportunities to attend to the needs of all students in the classroom were discussed.

*Keywords:* Multiplication Fact Fluency, Count-Bys, Single-Subject Design, Mild Cognitive Delays, Strategy Instruction.

# Introduction

Mastering basic math facts is essential for every child by the end of his or her elementary school education. Students need to be able to quickly retrieve them from memory and with little effort in order to later successfully tackle higher-level skills (Kilpatrick, Swafford, & Finell, 2001; Poncy, Skinner, & Jaspers, 2007; Woodward, 2006). Children who are not sufficiently fluent in basic addition, subtraction, multiplication, and division facts are likely to struggle not only in math, but in other subjects as well during their continuing school career (Stading, Williams, & McLaughlin, 1996). This is especially true for times tables. Koscinski and Gast (1993) point out that “… although students can develop accuracy and speed for addition and subtraction facts to 18 by continued use of counting strategies, counting methods become less effective for the multiplication facts to 81” (p. 533).

Unfortunately, a considerable number of elementary school children exhibit severe fact retrieval deficits (Geary, Hoard, & Bailey, 2012). The latest results from the National Assessment of Education Progress (National Center for Education Statistics, 2014) indicate that only 42% of students achieve an adequate level of automaticity in math fluency by grade 4. Studies with European samples do not give reasons for assuming that the respective students demonstrate more proficient skills in this area than those in the US (e. g. Gaupp, Zoelch, & Schumann-Hengsteler, 2004). There may be multiple reasons for this, ranging from family environments that offer little support for learning, poor teaching in schools, to inherent domain-general deficits in a child’s working memory (Swanson & Sachse-Lee, 2001).

There are, however, a number of research-based approaches to build math fact fluency in struggling learners. They include Copy, Cover, and Compare (CCC) (Skinner, McLaughlin, & Logan, 1997), Taped Problems (McCallum, Skinner, & Hutchins, 2004), Racetracks (Beveridge, Weber, Derby, & McLaughlin, 2005), Flash Cards (Skarr, Zielinski, Ruwe, Sharp, Williams, & McLaughlin, 2014), and many other interventions. One technique that has received only little attention in the literature so far, but appears to be very promising in supporting children to increase crucial multiplication fluency, is the Count-By strategy (Beattie, 1987, also known as Skip Counting (Wallace & Gurganus, 2005). It is an extension of counting by 5s or 10s but applied to other times tables (e. g. 3s, 4s, 6s, …) (McIntyre, Test, Cooke, & Beattie, 1991). When using Count-Bys, the teacher presents the concept of multiplication to the students as repeated addition. He or she illustrates a given task by using visual aids like posters or large index cards that depict the particular multiplication set with which the children need to become acquainted. For example, if students need to increase their fluency in solving 3s times tables, he or she presents them with a visual stimulus of the sequence of this series (see Figure 1).

--- insert Figure 1 here ---

Through repeated repetition (and oftentimes with the help of interactive “counting songs”[[1]](#footnote-1)) the children learn to retrieve the sequence from their memory. Subsequently, the teacher models how to solve respective multiplication problems by counting in steps of 3. For example, in order to come up with the correct response for 4 • 3, one needs to take four of those steps (3, 6, 9, 12). The teacher scaffolds the students' attempts as they try to solve problems on their own while thinking aloud, providing calibrated feedback, and ensuring task comprehension (Beattie, 1987).

One great advantage that the Count-By strategy has over some other ways of building multiplication fluency in boys and girls is that its aim goes beyond mere rote memorization of basic facts. By illustrating that multiplication is repeated addition, teachers can promote conceptual understanding. Children are thus better able to use their skills across a variety of applications (see Wallace & Gurganus, 2005).

The efficacy of CCC in helping students with math problems has recently been documented in a meta-analysis by Joseph, Konrad, Cates, Vajcner, Eveleigh, and Fishley (2012). Other interventions for increasing math fluency in children have also been extensively evaluated (see Codding, Burns, & Lukito, 2011 for a review). However, as of June 2014, the database PsycINFO lists only one scholarly paper that contains the term "Count-Bys” in its title (McIntyre, Test, Cooke, & Beattie, 1991) and one that mentions “Skip Counting” (Duvall, McLaughlin, & Cooke-Sederstrom, 2003). In both identified studies, a functional relationship between the instruction and increased fluency on the targeted multiplication facts was established.

The purpose of the present experiment was to contribute to the scarce body of existing literature by examining the effects of a Count-Bys intervention through a single-case analysis with a sixth grader, who struggled extensively with times tables. It was hypothesized that this technique would allow the student to reach mastery in those three single-digit multiplication sets that initially caused the greatest problems.

# Method

**Participant and Setting**

The participant was a 12-year old boy in sixth grade by the name of Justin (name altered for anonymity). He attended a special school for slow learners in a rural part of Western Germany. A multi-professional team had diagnosed him with mild cognitive delays when he was 6 years old. These kind of learning problems are basically defined as “… functioning like younger children in earlier developmental stages” (Klein, Cook, & Richardson-Gibbs, 2001, p. 55). In Germany, in the UK, and in a number of other European countries, mild cognitive delays are seen as one specific form of learning disability (LD). The term LD is used in a broader sense than in the U.S. and comprises moderate deficits in cognitive functions (like mild cognitive delays), different perception-processing disorders, and even problems of school achievement than are mainly caused by sociocultural or socioeconomic deprivation (Al-Yagon, Cavendish, Cornoldi et al., 2013; Opp, 1992).

Justin’s teacher suggested him for the study because of his remarkably low multiplication skills and the limited progress that he had made using other instructional approaches (especially different variations of the whole math method, see e. g. Stead & Semple, 1992). According to the Heidelberger Math Test (Haffner, Baro, Parzer, & Resch, 2005), Justin scored below the 5th percentile for the multiplication subtest. He was unable to successfully solve any of the 6s, 8s, and 9s problem sets. However, he was relatively fluent with basic addition facts. Justin was able to score slightly above the 30th percentile for this subtest.

The intervention took place in an unused classroom within his school. A female college student in special education from a large public university served as the research assistant who conducted the intervention. In addition to her teaching experience within the initial teacher education program, she possessed ample experience in working with children with mild cognitive delays in her part time job as a homework assistant. She was trained in the Count-By strategy by the first author. Lessons lasted between 15 and 35 minutes over a two week and one day period, and followed a standard instructional protocol (described below).

**Dependent Variables**

Remediation focused exclusively on the three basic fact sets with which Justin had little to no competency (6's, 8's, and 9's). Dependent variables were the number of correctly written digits in response to a worksheet containing ten multiplication problems for each fact set. Consequently, each test record consisted of 30 tasks altogether. Each day, Justin received a different worksheet, on which the problems were listed in a random order. A stopwatch was used to time how many items he was able to complete within 5 minutes.

**Experimental Design and Data Analysis**

A multiple baseline design (AB-extension) (Kazdin, 2011) across fact sets was applied to evaluate the intervention outcomes. In most single-case studies, baseline observations continue until the baseline stabilizes. However, this practice creates a bias in favor of identifying an intervention effect where none exists. Upward random variations followed by downward random variations could easily be misinterpreted as stabilization of the baseline (Todman, 2002). Dugard, File, and Todman (2012) suggest a different approach that Grünke, Wilbert, and Stegemann describe as follows:

An alternative … would be to come up with a preset number of total probes and a minimum number of baseline sessions as well as a minimum number of intervention sessions, and then to determine the beginning of the treatment by chance. This procedure cannot avoid random variations, but it turns potentially systematic nuisance variables into random nuisance variables, and thus increases the internal validity of the findings. (2013, p. 55)

In this experiment, a total number of 19 probes were defined. The baseline and the intervention phase had to overall consist of 15 daily measurement points. Four additional probes were designated for collecting follow-up data, which were evenly spread over a period of two weeks. We decided that both the baseline and the intervention phase for each multiplication set should at least consist of three probes. Thus, practicing any of the three sets could have started after the 3rd, the 4th, the 5th, the 6th, the 7th, the 8th, the 9th, the 10th, the 11th, or the 12th measurement point. A random drawing of one option for each set out of these ten alternatives (using paper slips and a small basket) yielded a starting point for teaching the 6s after the 5th probe, for teaching the 8s after the 5th probe, and for teaching the 9s after the 4th probe.

**Intervention**

Daily practice of each individual fact set took 10 minutes. Thus, the intervention could have lasted between 10 and 30 minutes, depending on the number of sets that were included during the session. Since the aforementioned research assistant started teaching Justin the 9s after the 4th probe, and the 6s as well as the 8s after the 5th probe, the instruction took 10 minutes on day five of the study, and 30 minutes from days six to 15. Justin was able to recite the relevant multiplication sequences almost error-free after the first two sessions that focused on the particular set (6s, 8s, or 9s). Therefore, after the second session focusing on a given basic fact set, the college student helped Justin to determine or recall different multiplication facts.

In order to encourage Justin to try hard to increase his math fact fluency and to fill out his daily probes over the whole length of the intervention, a motivational system was applied. He earned points for filling out the worksheets and for actively participating. At the end of each session, he could trade them for an edible reward (sweets or football stickers). (This external reinforcement strategy was consistent with the school's motivational system.).

# Results

As can be seen in Table 1, Justin’s baseline data ranged from 3 to 6 correctly answered multiplication problems (*M* = 4.00, 4.00, and 3.00). Before beginning the intervention phase, he was doubtlessly overburdened with the task. He left out the majority of the math problems and mainly focused on those for which he had quickly figured out the answer at the start of the instruction (those basic facts with 1,2, or 10 multiplicands -1 • 6, 2 • 6, 10 • 6, 1 • 8, 2 • 8, 10 • 8, 1 • 9, 2 • 9, and 10 • 9). The college student reported that during the baseline phase, Justin became frustrated at times, but never refused to work on his assignments.

--- insert Table 1 here ---

The onset of the instruction corresponded with a clear-cut increase in correct answers to the basic facts presented. Figure 2 distinctly illustrates the improvement in Justin’s performance. During the intervention phase, the mean number of his correct responses exceeded 9.00. Furthermore, he was able to accurately answer all of the multiplication problems by the end of the intervention. During the maintenance phase, Justin continued to demonstrate a high level of performance, retrieving the answers to most or all of the problems of three fact sets quickly and effortlessly from memory.

--- insert Figure 2 here ---

Pairwise Data Overlap (PDO, see Wolery, Busick, Reichow, & Barton, 2010) was used to determine the magnitude of the effects. PDO is calculated by identifying the overlap of all possible paired data comparisons between baseline and intervention phases. It usually produces more reliable results than other ways of generating an effect size from data reported in a single-case study (Alresheed, Hott, & Bano, 2013). For all multiplication fact sets, the PDO was 100%.

For the data from the baseline and the treatment phases, we also conducted a randomization (or shuffle) test. This is a useful method that considers all possible arrangements of the data, given the randomization procedure that was used in the experiment. Even though this technique is not yet well known among applied researchers, it has been employed in some single-case studies (e. g. Grünke, Wilbert, & Calder Stegemann, 2013; Mastropieri et al., 2009; Regan, Mastropieri, & Scruggs, 2005) and has been outlined in a large amount of theoretical papers and textbooks (e. g. Dugard, 2013; Dugard, 2014; Dugard, File, & Todman, 2012; Edgington & Onghena, 2007; Heyvaerta & Onghena, 2014). We therefore did not see the need to elaborate on the randomization test in detail at this point and instead refer the reader to the aforementioned literature.

In the case of this study, the intervention point was selected by chance for each fact set out of ten possible options. The total of the differences in absolute value across the two phases and across the three outcome measures (6s, 8s, and 9s) equaled (9.50-4.00) + (9.40-4.00) + (9.09-3.00) = 16.99. This sum was compared with total sums calculated from 103 = 1,000 selected arrangements of intervention starting points. The chance that 16.99 is the highest total out of all theoretically possible assignments is 1/1,000, making a p-value of 0.001 possible. If 16.99 was not the highest difference out of all potential options, but “only” one of the highest ten, it would still be part of the top 1% of the 1,000 alternatives. A specific Microsoft® Excel macro for AB multiple baseline designs, downloadable from the webpage that accompanies the textbook by Dugard et al. (2012) (www.routledge.com/books/details/9780415886932/), enables users to calculate an exact p-value for an observed value like 16.99. In this case, the differences between the mean baseline and mean intervention phase data across fact sets was statistically significant with an exact p-value of 0.002. The maintenance phase data was not considered in the calculation because the aforementioned website provides no macros for an AB-extension design.

# Discussion

The results of this study indicate that the Count-By strategy can be very effective in increasing multiplication facts fluency in struggling learners. Using this approach with a male sixth grader, who had previously not been able to develop a sufficient skill level in this respect, proved to be remarkably successful. During baseline, our subject was only able to produce on average 11 correctly written digits out of 30 responses on a given worksheet within a period of five minutes. By the end of this short intervention of ten to eleven, 10 minute-sessions per targeted fact set, he had reached mastery. The magnitude of the effects, as quantified by the PDO of the data, has to be considered very large. A randomization test, conducted on baseline-treatment phases across the three targeted fact sets (6s, 8s, and 9s) yielded a statistically significant result of p < 0.01. The student was able to keep up a high level of fluency after the instruction ended. During a short maintenance phase consisting of four probes evenly dispersed over a two-week period, our subject managed to succeed with over 90% of the presented multiplication problems. The outcomes thus replicate previous findings (Duvall, McLaughlin, & Cooke-Sederstrom, 2003; McIntyre et al.,1991), and are a good reason to consider the Count-By approach for children who experience significant difficulty learning basic multiplication facts.

However, the phenomenon that the performance of an individual changes in response to knowingly being part of an experiment (see e. g. Cook & King, 1968) could have limited the internal validity of this study. Typically, the boy received the usual classroom instruction from his teachers. In our experiment, however, he was taken out of his familiar environment and was individually trained by a female college student in a separate room of his school. The 1:1 attention could be partially responsible for the remarkable outcomes, as well as the fact that our subject knew that the purpose was to test the efficacy of a certain intervention. His level of cooperation might not have been as high as it was, had he just been one of many in a whole group of students.

Despite the limitations, the Count-By method may prove to be a very useful tool, and should be considered when planning instructions aimed at improving multiplication fact fluency in children. Future studies need to test the impact of this approach with a small group of learners, and then with an entire class as part of the standard instruction.

Teachers have to make sure that all of their students acquire a sufficient level of computation fluency by the end of their elementary school education. This competency seems to be a hallmark for being able to process more complex tasks at higher grade levels (Goldman & Pellegrino, 1987). Count-Bys are practical and easy to implement. No specific materials are needed. If a teacher were to use this strategy in his or her classroom, it would only take a couple of minutes each day. In fact, the application of this intervention seems so simple that even a fellow student should be able to take over the training of a struggling classmate like it is done in the Class-wide Peer Tutoring approach (Greenwood, Terry, Utley, Montagna, & Walker, 1993; Maheady & Gard, 2010; Rohrbeck, Ginsberg-Block, Fantuzzo, & Miller, 2003). Templeton, Neel, and Blood (2008) demonstrated in their review that peer tutoring can be a very effective way to deliver basic-facts mathematics interventions. This insight might open up a window of opportunities for teachers for economically using Count-Bys as a means of making sure that even in groups of very diverse students, no one falls behind in his or her endeavors to develop automaticity in multiplication facts. The strategy seems certainly eligible for applying it in a peer tutorial setting. Such a possibility could effectively relieve teachers of the burden of having to attend to every child in their classroom simultaneously. Additional research is warranted to establish the generalizability of the present findings and to investigate under which conditions Count-Bys can be economically taught in everyday classroom situations.

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Table 1

Correctly Answered Multiplication Problems in Five Minutes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | Baseline | Intervention | Maintenance |
| 6s | N (Probes)Raw Scores*M*Range | 53; 4; 5; 4; 4;4.003-5 | 108; 10; 10; 9; 10; 8; 10; 10; 10; 10;9.508-10 | 49; 10; 10; 10;9.759-10 |
| 8s | N (Probes)Raw Scores*M*Range | 53; 5; 6; 2; 4;4.002-6 | 1010; 9; 10; 9; 9; 8; 9; 10; 10; 10;9.408-10 | 410; 8; 10; 10;9.508-10 |
| 9s | N (Probes)Raw Scores*M*Range | 42; 2; 5; 3;3.002-5 | 118; 7; 9; 10; 10; 10; 9; 9; 8; 10; 10;9.097-10 | 46; 8; 10; 9;8.256-10 |

3, 6, 9, 12, 15, 18, 21, 24, 27, 30

Figure 1. *A poster to visualize the counting sequence for 3s*

Figure 2. *Number of accurately answered multiplication problems for each fact set in the baseline, the intervention, and the maintenance phase.*

1. The internet platform www.havefunteaching.com provides many different examples of how practicing multiplication facts can be varied and creative. [↑](#footnote-ref-1)