When Multiplication Facts Won't Stick: Could a Language/Story Approach Work?

A research study examining the effectiveness of the "Memorize in Minutes" curriculum

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Abstract

This study examined whether a story/language based method of teaching the multiplication facts would be helpful to students who previously had difficulty with the memorization of those facts. Using the curriculum *Memorize in Minutes* by Alan Walker (Walker, 2000), the researcher taught six fourth-grade students the multiplication facts (3s through 9s) over a period of 22 sessions of 30 minutes each. The participants showed marked growth in their acquisition of the facts. The participants who started with the least prior mastery of the facts had the most growth, and with the addition of extra time, achieved equal mastery with their peers. Unexpectedly, the participants retained and even later improved upon their newly acquired facts, as measured by the delayed posttest. These results warrant further research into the use of this curriculum for teaching the multiplication facts in both clinical and classroom settings.

Background

Most ETs have had the experience of helping a student learn or memorize something, and by the next day, the memorized fact will have completely vanished. No amount of review or practice seems to help; it is as if the information is coated with Teflon and slides right off the student's brain.

Such was my experience with a fifth grader, Sam, who had great difficulty memorizing the basic multiplication facts. We could drill a particular fact many times one day, and by the next day, that fact had vanished. We were not trying to build conceptual knowledge; this student's understanding of multiplication concepts was intact, and his engagement and motivation were in earnest; we were solely concerned with the act of memorization.

As do many students, Sam had a diagnosis of dyscalculia, or disability in math (as well as ADHD and dysgraphia). Yet, for our students with learning disabilities, problems with math extend far beyond the classroom: only 23% of our high school seniors graduate at the "proficient" or above level in math (National Center for Education Statistics, 2007). Presently, 58% of adults cannot calculate a 10% tip on a restaurant check (Phillips, 2007), and 27% of eighth graders cannot correctly shade in one third of a rectangle (NAEP, 2007). Success in everyday life, let alone in college or a technology-based job, requires competence in math.

Definition of disability in math. Developmental dyscalculia (DD), or mathematics learning disability (MLD), is defined as a "… specific learning disability affecting the normal acquisition of arithmetic skills" (von Aster & Shalev, 2007). DD/MLD, which is primarily a cognitive disorder, is considered a clinical diagnosis when a child's mathematics achievement is "substantially" below what would normally be expected, given the child's intelligence and educational opportunities (Mabbott & Bisanz, 2008). While problems in mathematics can be predicted as early as age 4 or 5 (Geary, Hamson, & Hoard, 2000), a full math disability may be clearly diagnosed by third grade (Fuchs, Powell, Seethaler, Cirino, Fletcher, & Fuchs, 2009). Researchers distinguish between low-achieving children who are likely to be weak in some, but not all, areas of math, and those who meet stricter criteria of an overall disability in math, which, depending on the criteria used, occurs in 3–8% of the population. Accordingly, a disability in math occurs at about the same rate as disability in reading.

Brain processes and memory. Underlying brain processes shown to have involvement in mathematical operations include the central executive function; attention; long-term, short-term, semantic, and working memory; procedural memory; and the visuo-spatial sketchpad, a component of working memory models that stores and manipulates visual and spatial information. Through the use of brain imaging, researchers are beginning to see a vast complexity in the ways different math processes involve different brain processes. Even a process as seemingly straightforward as remembering the answer to a math fact (i.e., just sheer rote automaticity, without asking for understanding or comprehension of that fact) is not completely understood. Most research speculates that delayed automaticity in facts is due primarily to a memory-based deficit (Levine, 2001).

To store memories, the brain uses a variety of systems, each of which plays a specialized role. While episodic memory collects our experiences in a way that allows us to replay them, semantic memory involves knowledge of facts, rules, symbols, meanings, and ideas that are not necessarily connected to specific incidents or events. Jerry W. Rudy, author of *The Neurobiology of Learning and Memory* (2008), summarizes by saying:

> *Many memory researchers believe the episodic memory belongs to a broader, long-term memory category called declarative memory, which not only includes episodic memory but also semantic memory. Semantic memory is believed to support our memory for facts and our ability to extract generalizations from multiple experiences.*

Rudy continues, "The content of semantic memory, however, is not tied to the place or context where you acquired it. *It is sometimes said to be context free*" [author's emphasis] (Rudy, 2008, p. 272). Rudy's concepts of "memory for facts" and "context-free memory" are relevant to math fact retrieval dysfunction in that math facts generally have no context. Retrieval is the ability to, upon demand, access and give expression to a specific fact, procedure, or piece of knowledge, within the generally accepted timeframe for that item. When there are problems with retrieval from memory, mastery of the multiplication math facts can be difficult.

Working memory, the temporary workspace in which thinking is done, is also consistently indicated as a major factor in DD/MLD and poor performance in math (Rotzer et al., 2009; Geary et al., 2000; Kercood & Grskovic, 2009). Whether working memory is a direct or indirect contributor to specific problems in the long-term storage and retrieval of math facts is unknown, but it is clearly required in the initial process of teaching and learning those facts and may influence their lack of consolidation into long-term memory (LTM).

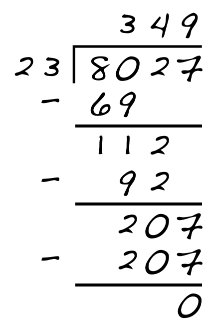
Researchers have speculated about how memory functions might interact in the context of a math deficit, suggesting that: (a) storage deficits cause deficient access to information in LTM, (b) deficits in attention resources cause problems in working memory, thus working memory insufficiently activates LTM, and/or (c) a general disruption of information retrieval from semantic memory is taking place (Kaufmann, Lochy, Drexler, & Semenza, 2004).

The central executive function and attention. During math learning, the central executive function appears to allocate working memory resources and to access knowledge from LTM (Kaufmann, 2002). Swanson & Jerman (2008) found that a deficit in the central executive component of working memory is a major risk in, and predictive factor for, mathematics learning disabilities in children with average intelligence. Children with math disabilities tend to do less mental rehearsal, a function of the central executive component, than children without math disabilities; it is that subvocal rehearsal that reduces memory decay (Swanson et al., 2008) and strengthens memory traces.

Additionally, children with DD/MLD, even those who do not have a formal diagnosis of ADHD, are consistently rated as being more inattentive than typically developing children and even children with learning disabilities (Raghubar et al., 2009). Children who are more inattentive make more math fact errors (Lee, Stansbery, Kubina, & Wannarka, 2005; Kaufmann & Nuerk, 2008). Children with DD/MLD may have specific difficulty inhibiting irrelevant information and associations inside of the executive component. Interventions that address inattention may be effective; even an act as simple as highlighting computation problems has been shown to increase the number of correct answers and reduce off-task behaviors (Kercood & Grskovic, 2009).

Developmental delay. An important recent finding is that a deficiency in procedural knowledge, which affects math fact retrieval, may be more reflective of a developmental delay than a cognitive deficit for some children (Raghubar et al., 2009). Children with DD/MLD tend to have mathematical processing abilities similar to those of younger children; they were found to have an understanding of multiplication comparable to their age-matched peers, but were less accurate, had slower retrieval rates, had smaller digit-span capacity in working memory, and had less-reliable back-up strategies, all comparable to younger children without DD/MLD (Mabbott & Bisanz, 2008). It may be that effective instructional techniques could compensate for, even on a temporary basis, the math fact retrieval/procedural deficit until such time as the child's development allowed for math fact retrieval using more traditional memory patterns.

Specific math deficits. Mathematics is built on a sequentially acquired knowledge of numeracy, operations, procedures, and concepts; and deficits can occur in one or a combination of those areas. To be successful at one step, a child must have properly mastered each prior step (VanDerHeyden & Burns, 2009). The inability to retrieve, or a delay in retrieving, math facts can undermine the solid acquisition of basic procedures such as multi-digit multiplication or division, which in turn undermines the later acquisition of fractions, decimals, percentages, pre-algebra, and so on. For example, solving a two-digit division problem can have as many as 16 steps and may require the use of six multiplication facts (among others) in calculating the solution (Figure 1).



16 steps:
3 division facts
6 multiplication facts
5 subtraction facts
2 bringing down steps

Figure 1. Illustration of two-digit division problem.

Some have suggested that students be given calculators or multiplication charts instead of asking them to memorize the facts. However, students with insufficient working memory already have a tendency to lose track of what they are doing, forgetting one part of a task while working on another; thus it is even more important that these particular students attain automaticity with multiplication facts.

Variables in intervention studies. Studies of multiplication intervention methods have been constructed using a wide assortment of variables with few consistent methodologies. Many of the interventions show good results, demonstrating that simply focusing more time and attention on learning the facts, using a thoughtful technique, yields good results. However, only 38% of the studies measure retention of the facts, so the long-term effectiveness of these approaches is still unknown (Codding, Hilt-Panahon, Panahon, & Benson, 2009). Informal, unique approaches to teaching multiplication facts, such as those invented by teachers, learning specialists, educational therapists, or tutors, are underrepresented in these studies.

The language/story approach. Sam's learning profile was noteworthy in that his above-average verbal/language capability lay in direct contrast to his below-average spatial/performance capability. While he was particularly disabled in math, which contains abstract concepts and offers content that has little context, he had an excellent memory for matters that contained meaning, such as those that occurred in language.

Indeed, children with DD/MLD usually have intact math-related language functioning and verbal ability (Mabbott & Bisanz, 2008), giving rise to the idea of a language/story based approach to studying math. One of the ways LTM is consolidated is through the "paired association" mode, where two pieces of information are stored together in memory (Levine, 2001). When weak mental representations (e.g., 3 x 4) are strengthened by a story, mnemonic, visualization, or activity, the chances of effective storage and retrieval can be greatly increased because they serve to anchor and connect that information.

My search for a solution for Sam led me to a unique book called *Memorize in Minutes*, by former Washington state teacher Alan Walker (Walker, 2000). In the book's curriculum, each number between 2 and 9 is assigned a rhyming mnemonic (3 = tree, 4 = door), and these mnemonics are then woven into a funny and visually memorable story; in this case, the story is about a tree, a door, and an elf; thus, tree x door = elf and 3 x 4 = 12.

Teaching this curriculum to Sam was nothing less than an astonishing experience. As he was taught the stories, he immediately and permanently remembered each one and could translate it to the fact in question. Needing to translate a story made his retrieval slower than if he had memorized the numerical answers, but compared with not being able to retrieve the fact at all, this route was acceptable. The results were so remarkable that I chose to study this curriculum as a master's research project.

In the course of this study I taught the Memorize in Minutes curriculum to a small group of participants over a series of 22 sessions, 2 or 3 days per week, in 30-minute increments. The participants in the study were six students in the fourth grade who had been identified by their school as having struggled in learning and remembering multiplication facts, despite plentiful classroom instruction and individual support. All participants were 9 or 10 years old and spoke English as a first language. Quantitative data were collected through administration of the pretest, posttest, and delayed posttests offered by the curriculum.

Pre-, post- and delayed posttests. The curriculum pretest included 36 problems, which covered the facts of the 2s through the 9s. Students were allowed up to 6 minutes to complete the test. After the conclusion of the intervention sessions, a posttest and a delayed posttest were administered. One change was made in these two latter tests: at the 6-minute mark, instead of ending the test, participants who had not yet finished were asked to put an asterisk on the problem they were working on and to continue working, creating an "untimed" version of the tests. In all cases, tests were finished within a few minutes of passing the 6-minute mark.

Structure and pacing. Although the original structure of the curriculum called for 30 teaching sessions, due to scheduling constraints, only 22 were able to be held. This resulted in the significant alteration of teaching of two new facts per lesson (instead of one) in 13 of the sessions. I felt that the resulting rushed pace reduced the chances for effective memory consolidation and caused a moderate amount of confusion in distinguishing between stories.

Pre-teaching. The pre-teaching of background concepts was important to the success of the learning of the stories. For example, not every participant was familiar with the program's story elements such as revolving doors, surfing, chefs, forts, and so forth.

Midway through the sessions, I realized that not all participants understood the rhyming associations critical to the mnemonic learning of the stories. For example, in the curriculum, 3 x 5 = 15 is translated to tree x hive = lifting. While four of the participants intuitively understood the rhymes (e.g., lifting = fifteen), and were facile in going back and forth between the numbers and the rhyming words, two of the participants did not hear the rhymes explicitly enough and thus made incorrect connections. I thus began to incorporate explicit instruction into the main lesson as to how the numbers and words rhymed in each phrase, syllabicated the sounds orally and visually, and had the group repeat the sounds aloud, separately and blended together.

Anchoring and review activities. Following the curriculum structure, each session contained a teaching, an activity, and a review segment, and every few sessions contained a quiz segment. Key features of the curriculum were the "anchoring activities," hands-on activities whose goal was to create strong visual, aural, or kinesthetic experiences of the story. Suggested activities included drawing the story with felt pens or shaving cream; modeling the story with pipe cleaners or clay; acting or dancing the story; writing extensions of the story or letters of correspondence; creating digital drawings or slides; and other activities such as creating board games, dioramas, or cartoons.

During the pretest, I noted that the allowance of 6 minutes to complete 36 problems in a paper and pencil test does not necessarily test true automaticity with the facts. To help address the need for automaticity, I added occasional individual verbal checks of progress. When instruction in one number (say, the 3s) had been completed, the participants did a quick individual verbal check before exiting the classroom. In less than 5 minutes, I saw first-hand the status of all the 3s facts and used that information to inform future instruction and review.

Findings

The students improved in their mastery of the multiplication facts in both expected and unexpected ways. Overall results can be seen in Figure 2.

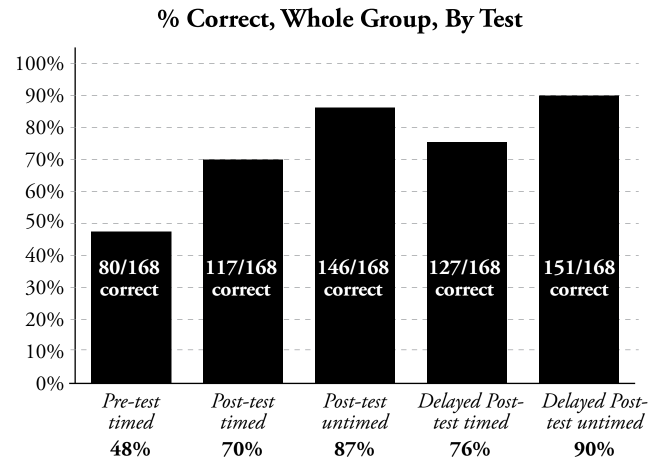


Figure 2. Percent Correct, Whole Group, by Test (delayed test was 14–20 days after the posttest)

Timed test improvement. The first key finding was the degree of overall improvement in the timed tests. The timed pretest score of 80 correct improved to 117 in the timed posttest, a gain of 46%.

Untimed test improvement. The second key finding was the amount of additional improvement that occurred by allowing participants a few extra minutes to finish their tests. The pretest had shown the existence of two distinct skill level groups; the three lowest participants averaged 7 correct, and the three highest had an average of 20 correct. The extra time allowed the three lowest students to increase their number of correct answers in the posttest from 47 to 69, an improvement of 47%. A similar gain was achieved in the delayed posttest with the additional time. I considered the possibility that the extra time allowed those students to use other strategies, such as fingers or skip counting, to arrive at the multiplication fact answers, but that was not visibly observed. Thus, the lower-skilled group accounted for almost 100% of the benefit from having extra time, and with this allowance, the distinction between the higher and lower groups had been eliminated by the end of the intervention. This has important implications in that the lower-skilled participants could now participate on a level playing field with their peers.

Delayed posttest improvement. The third key finding was the rate of retention of the studied multiplication facts as demonstrated in the delayed posttest. It was expected that some, and perhaps quite a bit, of deterioration of the multiplication facts would occur between the posttest and the delayed posttest. To the contrary, the participants showed further gains in both the timed and untimed versions of the delayed posttest over the posttest. While the increases were small, it is noteworthy that the scores did not decrease in the interim.

One interpretation of the improvement in the delayed posttest results could be that the participants had reached a place where they could use the multiplication facts functionally during their classroom math; that is, they were finally using the facts as their classmates did, and therefore were, in a sense, practicing during the normal course of their schoolwork. They were now engaged in the natural use of the facts that their peers had long been engaged in.

An additional explanation of the improvement in the delayed posttest scores might have to do with the process of memory consolidation. Anecdotally, clinical practitioners commonly report that material covered may not be consolidated efficiently for days, weeks, or even longer periods of time, unrelated to the amount of review. The data here speak to the need for future research into the process of memory consolidation for students with memory and learning challenges.

Combined improvement of allowing extra time and delaying testing. Perhaps the most striking result was the total improvement from the timed posttest to the untimed delayed posttest. The participants' scores improved from 117 to 151, or 29%, with *no further instruction*, but only with the combination of the allowance of extra time during testing and the delayed testing at 14–20 days after instruction ended. The benefit of these two features was again most dramatically seen in the participants in the lower starting group (Figure 3). In this figure, participants were ranked by their starting scores (e.g., Participant #1 had the highest score in the pretest, and so forth).

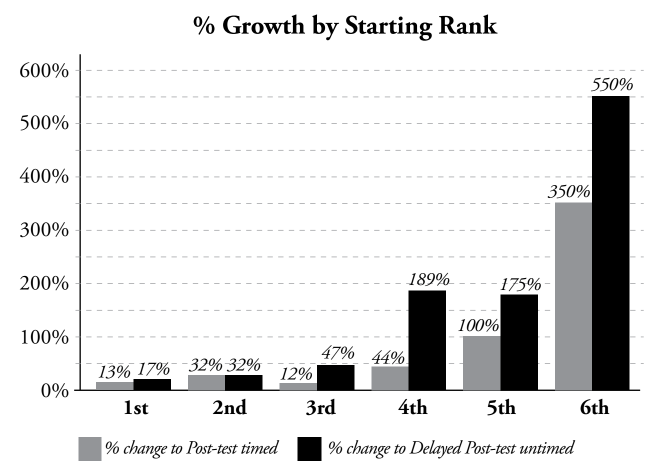


Figure 3. Growth From Extra Time and Delay Period, by Starting Rank

Of course, it could be said that the higher-ranking students had fewer facts to learn and therefore had less opportunity for growth. Nevertheless, the performance of the lower-ranking group participants has clear implications for clinical work: an alternative language/story based method of learning multiplication facts can provide immense benefit to those who struggle the most.

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