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A comparative analysis of massed vs. distributed practice on basic math fact fluency growth rates

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ABSTRACT

To best remediate academic deficiencies, educators need to not only identify empirically validated interventions but also be able to apply instructional modifications that result in more efficient student learning. The current study compared the effect of massed and distributed practice with an explicit timing intervention to evaluate the extent to which these modifications lead to increased math fact fluency on basic addition problems. Forty-eight third-grade students were placed into one of three groups with each of the groups completing four 1-min math explicit timing procedures each day across 19 days. Group one completed all four 1-min timings consecutively; group two completed two back-to-back 1-min timings in the morning and two back-to-back 1-min timings in the afternoon, and group three completed one, 1-min independent timing four times distributed across the day. Growth curve modeling was used to examine the progress throughout the course of the study. Results suggested that students in the distributed practice conditions, both four times per day and two times per day, showed significantly higher fluency growth rates than those practicing only once per day in a massed format. These results indicate that combining distributed practice with explicit timing procedures is a useful modification that enhances student learning without the addition of extra instructional time when targeting math fact fluency.

1. Introduction

Public education is currently facing a challenge in serving the diverse needs of its students, especially in mathematics. In 2011, the National Center for Educational Statistics (NCES) reported that only 40% of fourth-grade students and 35% of eight-grade students were performing at or above the proficiency level in math. This result indicates that more than half of fourth graders are currently struggling in math. Increased emphasis on accountability stemming from the implementation of No Child Left Behind (No Child Left Behind [NCLB], 2002) has educators continuously reminded of this deficiency and the expectancy to address this issue. However, limited time and resources make remediation of these deficits a challenge. For example, schools must have support personnel to help identify students in need of support as well as procedures and materials to remedy targeted math skill deficits. As a result, the need for evidence-based interventions designed to efficiently increase overall learning is ever present (Kratochwill, 2005).

In an effort to support mathematics instruction, researchers have identified and empirically validated a variety of practices, procedures, and interventions to increase accurate, fluent, and generalized responding. Some of these include explicit timing (ET; Van Houten & Thompson, 1976), cover, copy, and compare (CCC; Skinner, Turco, Beatty, & Rasavage, 1989), taped problems (TP;

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McCallum, Skinner, & Hutchins, 2004), and a variety of flashcard drill procedures (see Nist & Joseph, 2008). Although these various approaches have been identified to increase learning levels, more research is needed to identify ways that each of these intervention procedures can increase learning rates (Skinner, McCleary, Skolits, Poncy, & Cates, 2013). Being that the duration of the school day is fixed, researchers need to continually strive to find new instructional and intervention strategies or manipulate existing approaches to increase achievement levels in the same amount (or less) time (Skinner et al., 2013). An example of this striving was highlighted by Skinner, Belfiore, Mace, Williams-Wilson, and Johns (1997). They compared CCC using verbal and written responding to increase basic math fact fluency. Results showed that, when controlling for opportunities to respond, subjects learning level increases were relatively similar but completed the problems in less time when responding verbally. The use of verbal responding with the CCC procedure led to more learning in less instructional time and provided practitioners with a relatively easy way to modify CCC to speed up student learning.

Instructional efficiency that has been accomplished in the past is by increasing rates of responding, increasing learning trial strength, or both (Skinner, Fletcher, & Henington, 1996). Some identified practices achieving this goal include altering response topographies (Gardner, Heward, & Grossi, 1994; Skinner, Ford, & Yunker, 1991; Skinner et al., 1997), limiting breaks and increasing pace (Darch & Gersten, 1985), decreasing intertrial intervals (Skinner, Belfiore, & Watson, 2002), setting time limits (Derr & Shapiro, 1989), increasing the saliency of prompts and cues (Van Houten & Rolider, 1990), and providing feedback, goal setting and self-monitoring, and delivery of positive reinforcement (Van Houten, Hill, & Parsons, 1975). Although this list of strategies and practices is encouraging, researchers need to continue to investigate low-cost, low-effort approaches to modify existing interventions that produce increased learning per instructional minute (i.e., learning rate). One possible method to modify interventions that has seen little attention in the applied literature is the distribution of practice across time.

1.1. Distributed practice

The concept of distributing practice over time versus massing practice into one time period has been studied since the early days of psychological research. The beginning concept was first documented by Ebbinghaus (1885/1913). Using himself as a subject, Ebbinghaus determined that distributing learning sessions of nonsense syllables with controlled response trials was superior to similar stimuli learned in one session. The superiority of distributing learning and practice over massed learning was replicated by many early researchers (Cook, 1934, 1944; Jost, 1897; Reed, 1924; Ruch, 1928; Thorndike, 1912).

This psychological principle has since become one of the most established topics in learning and memory research, being referred to as the "spacing effect," "lag effect," or the "distributed practice effect" (for review, see Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006). Although a staple in experimental psychology, the majority of literature regarding distributed versus massed practice has been devoted to basic cognitive research for the purpose of further developing the theoretical understanding of this phenomenon. Studies have identified various factors mediating the effects of the distributed practice effect. For example, the effects of distributed practice show a positive relation with lag (length of space or items) between study presentations as well as negative relations with age and developmental level of participants, complexity of task, and effects on temporal position and retention (for reviews, see Cepeda et al., 2006; Donovan & Rudosevich, 1999; Lee & Genovese, 1988). A great many other studies focus on the development of theories and models to explain the phenomena (Cepeda, Vul, Rohrer, Wixted, & Pashler, 2008; Cepeda et al., 2006; Glenberg, 1979; Greene, 1989; Hintzman, 1974; Pavlik & Anderson, 2003).

Although there are exceptions to the principle, the collection of basic research has identified very robust findings regarding the benefit of distributed practice over massed practice for learning and memory. Although the potential for improved educational impact is obvious, additional studies focusing on applied educational settings could strengthen educators understanding of how to apply distributed practice procedures to bolster academic achievement.

Fortunately, there is a growing applied research base on distributed versus massed practice in some academic areas, and the majority of this research base complements the findings of basic research. Such distributive effects have been replicated in acquiring reading skills (Dempster, 1989; Seabrook, Brown, & Solity, 2005; Sobel, Cepeda, & Kapler, 2011), foreign language vocabulary (Bahrick, Bahrick, Bahrick, & Bahrick, 1993; Cepeda et al., 2009), and science knowledge (Reynolds & Glaser, 1964; Vlach & Sandhofer, 2012).

Although this literature base has supported the enhanced effects of distributed practice, a small number of studies have revealed a possible treatment-by-time interaction. Specifically, these studies indicate an interaction between spacing (massed versus clustered versus distributed) and time of assessment relative to the final treatment session. Fishman, Keller, and Atkinson (1968) studied the effect of massed versus distributed practice in computerized spelling drills of fifth-grade students. Although the students studying under massed conditions performed better initially, the distributed condition outperformed the massed practice group 10 and 20 days later. Bloom and Shuell (1981) studied high school students' learning and retention of second-language vocabulary under massed or distributed practice conditions (one 30-min session or three 10-min sessions across three consecutive days). Results indicated that whereas both groups were nearly identical on tests given immediately after completion of the study, those in the distributed practice condition performed better than their massed counterparts seven days after the conditions. Although these results may seem to be inconsistent with past research, magnified effects of distributed practice in retention measures are generally observed (Cepeda et al., 2006).

A limited number of studies have directly observed the distributive practice effect on math skills. Rohrer and Taylor (2006, 2007) provided college students a tutorial on how to find the number of permutations for a sequence of items, then randomly assigned participants to practice the procedure in one massed session or in two sessions distributed across a 1-week period. Results showed that the group practicing in a distributed fashion received higher assessment scores after 1 week (Rohrer & Taylor, 2007) and also after