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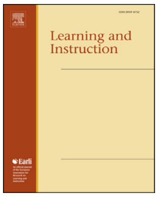

Spacing in a simulated undergraduate classroom: Long-term benefits for factual and higher-level learning

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ABSTRACT

Despite showing robust benefits in lab-based research, there remain relatively few studies exploring the spacing effect in educational contexts with meaningful materials. In this study, participants ($N = 169$ undergraduate students) attended a simulated university lecture where they were presented with natural science curriculum material. Participants reviewed the material either one day or eight days after the lecture via an online review. Participants completed a final test on the material five weeks after each respective review. During the review and final test participants were asked both factual and higher-level (application) questions. Results showed that reviewing material eight days after the lecture led to better final test performance for both types of questions when compared to reviewing only one day after the lecture. This study suggests that spaced review is a robust and effective strategy that can be and should be adapted to classroom practice.

1. Introduction

The spacing effect — a memory advantage that occurs when study sessions are spaced apart in time — is a widely recognized phenomenon in cognitive psychology. It is known to improve long-term retention and thus has clear implications for educational settings (Carpenter, Cepeda, Rohrer, Kang, & Pashler, 2012; Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006; Pashler, Rohrer, Cepeda, & Carpenter, 2007). However, few experiments have explored the benefits of spacing in actual classroom settings with real-world curriculum and educationally relevant inter-study and retention intervals (Dempster, 1988). Therefore, it might be premature to suggest that spacing be systematically implemented in real-world classroom environments. This study introduces a spacing manipulation into a simulated classroom, using undergraduate curriculum material, educationally relevant inter-study intervals of 1 day and 8 days, and a retention interval of 35 days.

1.1. The spacing effect in the laboratory

To date, hundreds of studies have demonstrated that spaced learning reliably and robustly improves long-term retention across a wide variety of laboratory-based memory tasks (for reviews see Cepeda et al., 2006; Donovan & Radosevich, 1999; Janiszewski, Noel, & Sawyer, 2003). For example, it has been found to benefit name learning (e.g., Carpenter & DeLosh, 2005), object learning (e.g., Cepeda et al., 2009), vocabulary learning (e.g., Bahrick, Bahrick, Bahrick, & Bahrick, 1993; Kornell, 2009), fact learning (e.g., DeRemer & D'Agostino, 1974), text passages (e.g., Gordon, 1925; Rawson & Kintsch, 2005; Verkoeijen, Rikers, & Ozsoy, 2008), mathematical concepts (e.g., Rohrer & Taylor, 2006; 2007), motor skills (e.g., Baddeley & Longman, 1978; Mackay, Morgan, Datta, Chang, & Darzi, 2002; Moulton et al., 2006; Panchuk, Spittle, Spittle, & Johnston, 2013; Shea, Lai, Black, & Park, 2000), and musical skills learning (e.g., Simmons, 2012).

1.2. The spacing effect and higher-level learning

The majority of spacing studies, however, have used verbal or factual material as the to-be-learned stimuli (e.g., 839 effect sizes reported in Cepeda et al., 2006), where participants are not required to do anything with the information other than retrieve it from memory (Moss, 1995). Yet, in educational settings, it is rare that students are required to simply retrieve isolated pieces of information from memory; instead, they often must manipulate and apply the remembered information to answer more complex, higher-level questions. In comparison to hundreds of factual material spacing studies, the number of studies examining the effect of

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spacing on higher-level learning is limited. Some of the higher-level skills examined so far include learning of mathematical (e.g., Gay, 1973; Pyle, 1915; Rohrer, 2009; Rohrer & Taylor, 2006; 2007) and science concepts (e.g., Gluckman, Haley, & Sandhofer, 2014; Reynolds & Glaser, 1964; Vlach & Sandhofer, 2012), inductive category learning (e.g., Kang & Pashler, 2012; Kornell & Bjork, 2008; Vlach, Sandhofer, & Kornell, 2008; Wahlheim, Dunlosky, & Jacoby, 2011; Zulkiply & Burt, 2013; Zulkiply, McLean, Burt, & Bath, 2012), and the ability to make complex judgments (e.g., Helsdingen, van Gog, & van Merriënboer, 2011). These studies demonstrate that the spacing effect exists not only for simple fact learning but also for the learning of more complex material. Despite this more recent accruement of evidence, studies examining the effect of spacing on higher-level learning are few. Ecologically valid studies that use educationally relevant materials, timescales, and methods are needed before specific recommendations to educators can be made (e.g., Dempster, 1988; Dunlosky & Rawson, 2012).

1.3. The spacing effect in the classroom

This study contributes to the growing literature exploring spacing effect benefits in applied settings. Currently, there are some studies examining the spacing effect in the classroom (e.g., Balch, 2006; Bird, 2010; Bloom & Shuell, 1981; Carpenter, Pashler, & Cepeda, 2009; Fishman, Keller, & Atkinson, 1968; Küpper-Tetzel, Erdfelder, & Dickhäuser, 2014; Seabrook, Brown, & Solity, 2005; Smith & Rothkopf, 1984; Sobel, Cepeda, & Kapler, 2011; Yazdani & Zebrowski, 2006; see Kiepert, 2009, for a review). One possible reason for the lack of spacing effect classroom studies, in comparison to hundreds of laboratory studies, is the abundance of extraneous variables (noise) present in the classroom that can affect the success of a spacing intervention (e.g., classroom peer distractions, students' previous knowledge of the subject, high attrition rates, class schedule-induced time constraints, etc.). In comparison, many laboratory studies use computerized paradigms (e.g., a word pair presented on a screen for a specified number of seconds), where participants are tested individually, their attention is directed to the computer screen, and they are often required to learn material to some criterion before advancing to the next part of the experiment. In the classroom, however, students are part of a larger group of peers, the mode of delivery of the lesson is the decision of the teacher (often a lecture format), and students' attention may be diverted for any number of reasons, placing into question how well the information is initially understood. When one considers these complexities of classroom practice, it is easy to see how the benefits of spacing may be weaker in the classroom than in a controlled laboratory setting.

Many existing classroom studies use simple verbal or factual material as stimuli. For example, Carpenter et al. (2009) looked at the effects of testing and spacing in 8th-grade students learning U.S. history facts. After being taught in class, history facts were reviewed after 1 week, 16 weeks, or not at all, with the final test taking place 9 months later. Review took the form of testing followed by feedback or simply re-reading the facts. The study found significant testing effect benefits and spacing effect benefits approached significance with $d = 0.5$, $p = .06$. Sobel et al. (2011) taught fifth-graders the definitions of eight GRE vocabulary words. Half of the words were reviewed immediately, and half one week later. After a five week retention interval, words reviewed one week after initial learning showed spacing effect benefits with $d = 0.5$, $p = .004$. Bloom and Shuell (1981) divided a high school French class into two learning groups. One group learned 20 French words in three 10-min sessions spaced over three consecutive days. The other group learned the same 20 French words in a single 30-min session massed in one day. In a final free-recall test four days after learning the words, students in the spaced learning group outperformed students in the massed learning group, with $d = 1.0$, $p < .01$ (see also Balch, 2006; Fishman et al., 1968; Küpper-Tetzel et al., 2014).

Only a handful of classroom or classroom-like studies have examined the spacing effect with complex study materials as stimuli. For example, Yazdani and Zebrowski (2006) tested whether the scheduling of plane geometry homework (defined as either massed daily drilling after each covered topic or spaced homework over an extended period of time) would result in improved test scores six weeks later. The study's significant findings supported a shift towards a “non-drilling” method of instruction, strongly supporting spaced instructional design. Bird (2010) examined the ability of undergraduate learners of English to detect and correct verb morphology over a 14-week semester, with inter-study intervals of 3 and 14 days, and retention intervals of 7 and 60 days. After a 60-day retention interval, students benefited from the spaced (14 days) schedule of learning.

However, certain limitations of these studies should be mentioned. Bird's (2010) study, while having notable ecological validity, utilized five study sessions throughout the entire semester and engaged 5 h of class time, where students practiced the task of identifying mistakes in simple past/present perfect/past perfect sentences. While definitely a complex task and a well-designed experiment, it seems unlikely that this amount of class time would be spent on practice of the same material outside of this experiment. Also, this study had five study sessions, making it difficult to compare to the rest of the spacing effect literature, which typically employs two (or rarely three) study sessions. The same can be said for Yazdani and Zebrowski's (2006) study, which also had superior ecological validity and was conducted in a real high school classroom with actual school curriculum, but with less than ideal experimental control (e.g., the spacing manipulation had seven unequally spaced study sessions with an unequal amount of review completed at each session).

These studies highlight the difficulties researchers might encounter when translating psychological phenomena into educational settings. Time and curriculum constraints as well as practicality and efficacy of the way in which spacing can be implemented in the classroom often present challenges. In the current study, we propose a hybrid between a laboratory and a classroom setting as a step towards addressing some of these challenges.

1.4. Operational definition of higher-level learning

A major goal of the current study was to examine whether spaced review could improve higher-level learning; therefore, it was critical that we operationally defined what this term meant in the context of our study. We looked at the literature on critical thinking (e.g., Case, 2009; Ennis, 1987; Halpern, 2003; Kuhn, 1999; McPeck, 1981) to set operational definitions for “simple” and “complex” questions in the current study. After much consideration, we decided to use the Bloom's taxonomy of educational objectives framework (Bloom, 1956; Krathwohl, 2002) that is commonly used as the basis of assessment of student achievement in Canada (e.g., Ministry of Education, 2008). It consists of six hierarchical learning categories: Knowledge (recalling a fact), Comprehension (understanding meaning of a concept), Application (applying a concept to a new problem), Analysis (separating a concept into component parts), Synthesis (creating a new meaning or structure), and Evaluation (making judgements about the value of ideas or arguments). Our study required both simple and complex learning that could be objectively evaluated. We defined simple questions as those that assessed Bloom's Knowledge level. These were factual questions