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Brief Report

Equal spacing and expanding schedules in children's categorization and generalization

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ABSTRACT

To understand how generalization develops across the lifespan, researchers have examined the factors of the learning environment that promote the acquisition and generalization of categories. One such factor is the timing of learning events, which recent findings suggest may play a particularly important role in children's generalization. In the current study, we build on these findings by examining the impact of equally spaced versus expanding learning schedules on children's ability to generalize from studied exemplars of a given category to new exemplars presented on a later test. We found no significant effects of learning schedule when the generalization test was administered immediately after the learning phase, but there was a clear difference when the generalization test was delayed by 24 h, with children in the expanding condition significantly outperforming children in the equally spaced learning condition. These results suggest that forgetting and retrieval dynamics may be lower level cognitive mechanisms promoting generalization and have several implications for broad theories of learning, cognition, and development.

Introduction

Categorization and generalization are fundamental processes in cognition and development. Consequently, researchers have examined multiple factors in the learning environment that promote the

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acquisition and generalization of categories. A recent relevant finding is that the *timing* of learning events may be particularly important for promoting generalization; distributing the presentation of category exemplars across intervals of time has been shown to promote more generalization than massing category exemplars together in immediate succession (e.g., Birnbaum, Kornell, Bjork, & Bjork, 2013; Vlach, Sandhofer, & Kornell, 2008). To date, researchers have presented learners with category exemplars on spaced schedules with roughly equal intervals of time between presentations. The current study extends this work by examining how distributing learning events across variable amounts of time affects children's category acquisition and generalization.

The spacing effect in memory and generalization

A considerable body of research has examined the conditions under which the timing of learning events promotes and/or deters memory. The most highly replicated and robust finding of this literature is commonly termed the *spacing effect* (Ebbinghaus, 1885/1964; see Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006, for a review). The spacing effect refers to the finding that memory is enhanced on a delayed test when learning events are distributed in time rather than massed in immediate succession. Hundreds of experiments have observed a spacing effect in a wide variety of memory tasks (Cepeda et al., 2006). In these studies, learners are presented with the same information multiple times, such as lists of words, with intervals of time filled with unrelated events between each presentation. After a delay, participants are asked to recall the exact information presented earlier in the experiment, such as the words from the list.

Only recently, however, has the spacing effect been studied in the context of categorization and generalization tasks (Birnbaum et al., 2013; Kang & Pashler, 2012; Kornell & Bjork, 2008; Kornell, Castel, Eich, & Bjork, 2010; Rohrer, 2012; Vlach, Ankowski, & Sandhofer, 2012; Vlach et al., 2008; Wahlheim, Dunlosky, & Jacoby, 2011). Categorization and generalization tasks differ from memory tasks because they require learners to aggregate exemplars, abstract relevant and irrelevant information across presentations, store information, and (at test) generalize this information to a new instance of the category. This body of research has revealed that spacing the exemplars of a given category, versus presenting exemplars in immediate succession, promotes generalization at a delayed test. Indeed, this finding has been observed across the lifespan, including during childhood (e.g., Vlach et al., 2008, 2012), during adulthood (e.g., Birnbaum et al., 2013), and during older adulthood (with interleaved learning paradigms; e.g., Kornell et al., 2010).

In studies of categorization and generalization processes in children, the children are typically presented with a series of category exemplars, often novel objects that share a common perceptual feature (e.g., shape) but also have differing perceptual features (e.g., color, texture). Each category exemplar is paired with a novel linguistic label (e.g., "wug"). In studies on the effects of spacing (Vlach et al., 2008, 2012), the exemplars have been presented on either a massed schedule, in which category exemplars are presented in immediate succession, or a spaced schedule, in which category exemplars are separated in time. At test, children are shown a set of objects that includes a novel exemplar of a studied category and are asked to identify the object that is, say, a "wug." The current study used a similar paradigm.

To date, in research on spaced learning schedules in categorization and generalization tasks, learners have been presented with exemplars of a given category with an equal, or roughly equal, temporal separation between successive exemplars. That is, information has been presented on spaced schedules with an equal amount of time between learning events (e.g., Birnbaum et al., 2013; Vlach et al., 2008, 2012). However, research has yet to examine categorization and generalization on variable learning schedules. Thus, in the current study, we examined children's generalization across both equal and variable time schedules. Given that there are an infinite number of possible variable learning schedules, we focused on a particular schedule—an expanding interval schedule—that has often been compared with a uniform schedule in research on memory for verbal materials, such as names or vocabulary items.