# Temporal Dynamics of Categorization: Is There a Best of Both Worlds?

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## Introduction

Categorization is a fundamental process in cognition, development, and education. Beginning early in life, infants and children learn categories of objects, people, and more, creating a conceptual framework for understanding the world. When entering formal schooling contexts, teachers present students with multiple examples of educational concepts with the hope that students will generalize these examples beyond the classroom. To later generalize knowledge, children must abstract the similarities and differences across examples of a category or concept. For instance, when children learn the category of "cat," children must abstract across the examples of "cat" that they have experienced to notice the similarities (e.g., body shape) and differences (e.g., color). This knowledge will allow children to classify and generalize characteristics of "cat" to new cats.

Given the central role that categorization plays in cognition, researchers have sought to determine the characteristics of the learning environment that promote children's ability to generalize knowledge. This work has shown that the timing of learning affects children's categorization. One line of work has demonstrated that *viewing multiple instances of a category simultaneously* facilitates category acquisition and generalization (e.g., Ankowski, Vlach, & Sandhofer, 2013; Gentner, 1983; Gick & Holyoak, 1983; Oakes & Ribar, 2005; Vlach, Ankowski, & Sandhofer, 2012). In a typical paradigm, children are presented with multiple novel objects that are labeled with the same novel linguistic label (e.g., "This is a wug!"). The novel objects are presented on two schedules: simultaneous or massed. In simultaneous presentations, novel objects are presented at the same time so that children can visually inspect all of the exemplars together during learning. In massed presentations, novel objects are presented sequentially so that children can only visually inspect one exemplar at a time. At an immediate test, learners are asked to generalize to a novel exemplar of the category (e.g., identify a new "wug"). This research has consistently shown that visually comparing multiple instances of the same category promotes generalization to a greater degree than viewing the same number of instances presented in immediate succession (i.e., massed presentations).

Another line of research has come to a different conclusion. Many studies on spaced learning have demonstrated that *viewing multiple instances of a category across time* facilitates category acquisition and generalization (e.g., Carvalho & Goldstone, 2014; Gluckman, Vlach, & Sandhofer, 2014; Kornell & Bjork, 2008; Vlach, et al., 2012; Vlach & Kalish, 2014; Vlach & Sandhofer, 2012; Vlach, Sandhofer, & Kornell, 2008; Vlach, Sandhofer, & Bjork, 2014; for a review, see Vlach, 2014). In these studies, categories are presented to children on two schedules: a spaced schedule or a massed schedule. In both schedules, novel objects are presented sequentially so that children can only visually inspect one exemplar at a time. In massed presentations, the novel object presentations are presented in immediate succession. In spaced presentations, the novel object presentations are separated by intervals of time, in which children participate in an unrelated activity. After a retention interval, learners are asked to generalize to a novel exemplar. The consistent finding in this work is that presenting learners with instances of a category on a spaced schedule promotes generalization to a greater degree than presenting the same number of instances on a massed schedule.

## At the Same Time or Apart in Time?

These two lines of research present a seemingly paradoxical set of results: How is it that comparison, the presentation of instances at the *same time*, and spaced learning, the presentation of instances *apart in time*, both facilitate children's categorization? In my work, we have begun to resolve this paradox by directly comparing children's performance on multiple schedules in a novel noun generalization task. In two experiments (Vlach et al., 2012), children were randomly assigned to learn about object categories on a simultaneous, massed, or spaced schedule. Children's generalization was tested at an immediate test, consistent with comparison paradigms, or after delay, consistent with spaced learning paradigms. The results revealed that the testing timescale led to very different results. Children had stronger performance in the simultaneous condition at the immediate test. In contrast, children had stronger performance in the spaced condition at the delayed test. Thus, we concluded that timescale at which children are required to generalize knowledge is a determining factor in whether comparison and spaced learning are advantageous for learning.

Why does timescale matter? In line with structure mapping theories of comparison (Gentner, 1983), I have proposed that simultaneous presentations reduce demands on visual attention and short-term memory, allowing children to spend more cognitive effort mentally comparing exemplars (Vlach et al., 2012). Consequently, children have higher performance on simultaneous schedules at an immediate test. However, this easy encoding comes at a cost; children do not get practice retrieving from memory what they have learned. In line with forgetting-as-abstraction theory (Vlach, 2014), I

have proposed that spaced learning leads to higher performance at a delayed test because spaced schedules (a) provide children with practice retrieving knowledge from memory and (b) allow irrelevant information (e.g., irrelevant features) to be forgotten over time. In brief, I have proposed that comparison and spaced learning support different information-processing components, and thus support learning at different timescales.

## Is There a Best of Both Worlds?

The talk will focus on emerging research in my lab that addresses the question: Can simultaneous and spaced presentations be combined to optimize children's generalization? I have long hypothesized that, because simultaneous and spaced presentations support differing information-processing components (i.e., visual attention and short-term memory vs. long-term memory), a learning schedule that combines the two presentation methods should be optimal. That is, a combined schedule may promote children's generalization to a greater degree than a simultaneous or spaced schedule.

My lab is examining this research question across several experiments, with different age groups (e.g., younger vs. older children vs. adults), different stimuli (e.g., object categories and science concepts), and different timescales (e.g., ISIs of seconds vs. days). In some experiments, the combined condition is a *clumped* condition, in which two category exemplars are presented in immediate succession, but spaced in time with other exemplars (e.g., two exemplars in immediate succession on a Monday and two exemplars in immediate succession on a Tuesday). In other experiments, the combined condition is a *distributed pairs* condition, in which two exemplars are presented simultaneously, but spaced in time with other exemplars (e.g., two exemplars presented simultaneously on a Monday and two exemplars presented simultaneously on a Tuesday). Children's ability to generalize categories is measured at a delayed post-test.

Across experiments, the preliminary results are consistent: the answer to this research question is likely 'no'. That is, on the group level, clumped and distributed pairs presentations do not lead to stronger performance than simultaneous or spaced presentations. However, a sub-set of the sample does benefit from a combined schedule. This finding suggests that future research will need to take an individual differences approach to understanding why some children benefit from a combined schedule whereas other children benefit from a simultaneous or spaced schedule. For instance, children with low long-term memory abilities may need as much spacing as possible to support this cognitive domain. The talk will end with a discussion of what these results mean for theories of categorization, such as structure mapping theory and forgetting-as-abstraction theory. Importantly, these results will be connected to real-world teaching practices, in which educators must decide whether to present concepts simultaneously, across time, or some combination of the two presentation methods.

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