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Learning Painting Styles: Spacing is Advantageous when it Promotes Discriminative Contrast

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Summary: Repetitions that are distributed over time benefit long-term retention more than when massed. Recent research has suggested that the advantage of spacing may extend to induction learning–learners were better able to identify the artists of previously unseen paintings when, during training, artists' paintings were spaced (paintings by different artists were interleaved) rather than massed (a given artist's paintings were blocked and presented consecutively). Increasing temporal spacing between paintings while maintaining a presentation sequence that was blocked by artist produced test performance no better than massed presentation (both worse than interleaved presentation) (Experiment 1). Displaying paintings by different artists simultaneously produced test performance as good as interleaved presentation and better than massed presentation (Experiment 2). Our findings argue that spacing benefits perceptual induction learning not because of increased temporal spacing per se but rather because interleaving paintings by different artists enhances discriminative contrast between the artists' styles. Copyright © 2011 John Wiley & Sons, Ltd.

Keywords: spacing effect; distributed practice; perceptual category learning; inductive learning

Performance on a wide variety of tasks is improved when repetition of study or practice is distributed over time rather than massed, even when total study or acquisition time is held constant. Referred to as the spacing effect, it is considered one of the most robust and replicable phenomena in behavioral science (Dempster, 1996; Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006), and has been demonstrated in domains as diverse as memory for verbal material—e.g. nonsense syllables, words and sentences (e.g. Underwood, 1970), memory for pictures (e.g. Hintzman & Rogers, 1973), arithmetic skill acquisition (e.g. Rickard, Lau, & Pashler, 2008), and motor or procedural learning (e.g. Baddeley & Longman, 1978).

Although the spacing effect appears to be robust and important for educational practice, one might argue that in many (if not most) real-world situations, the importance of learning and retaining specific instances or episodes from the past is limited because the probability of encountering the exact same event or circumstance again in the future is low. More important, one might say, is to identify abstract patterns and principles from past examples and to transfer this knowledge to new examples. This line of reasoning would argue for stressing inductive learning (i.e. learning to generalize from relevant prior encounters). Until recently, however, there was no evidence to suggest that spacing could benefit inductive learning. Indeed, some have suggested that, whereas spacing enhances memory, it might be detrimental to induction (Rothkopf, as cited in Kornell & Bjork, 2008)—since spacing exemplars from a given category or concept could hinder the noticing of common features that define that category or concept (e.g. Underwood, 1952; Kurtz & Hovland, 1956).

Kornell and Bjork (2008) investigated this directly using a task of learning the painting style of individual painters. Their results showed that, contrary to the suggestions just described, spacing substantially enhanced performance in this inductive learning task. In their study, they presented subjects with paintings by 12 artists (displayed one at a time), with the instruction to learn the style of each artist. In the massed condition, the paintings were blocked by artist, such that a number of paintings by a given artist would appear consecutively. In the spaced condition, paintings by different artists were interleaved, such that no two paintings by a given artist appeared consecutively. Subjects were subsequently presented with paintings by the same 12 artists, which they had not previously been shown, and had to pick which of the 12 artists was responsible for each painting. Across two experiments, test performance was markedly better in the spaced as compared with the massed condition (see Kornell, Castel, Eich, & Bjork, 2010, for a replication of this result in older adults).

One potentially important question that these striking findings of Kornell and colleagues leave unanswered is whether the advantage of spacing was due to increased temporal spacing between paintings by the same artist or due to the interleaving of paintings by different artists (both variables were manipulated at the same time). Also, by using paintings from 12 artists, it is possible that the spacing benefit they observed was at least partly due to the effect of spacing on memory (i.e. learning which style is associated with which of the 12 artists) and less so to any effect on induction *per se*.

The aims of the present study were the following: (1) to determine whether temporal spacing or interleaving (or perhaps both) underlies the spacing effect seen in the learning of artists' painting styles and (2) to examine whether the spacing advantage observed by Kornell and colleagues persists when the memory load is substantially reduced. Across two experiments, we compared the impact of a number of study conditions on learning of the painting styles of three artists. In all conditions, the set of paintings shown, and the total time spent viewing

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each painting, was always equated across all of the conditions. In Experiment 2, in addition to examining the *Massed* and *Interleaved* conditions, we compared a third condition in which paintings were presented three at a time, one each by a different artist (*Simultaneous Different*).

EXPERIMENT 1

Experiment 1 examined the efficacy of four study conditions. Two conditions—*Massed* and *Interleaved*—were essentially the same as the two used by Kornell and Bjork (2008). We included two additional conditions: one that featured the same temporal spacing between paintings by a given artist as in the Interleaved condition (by the insertion of unrelated filler material) but in which the sequence of paintings was blocked by artist (*Temporal Spaced*), and another that was identical to the Massed condition except that the paintings (by a given artist) were presented four at a time (*Simultaneous Massed*).

If the spacing advantage observed by Kornell and colleagues (e.g. Kornell & Bjork, 2008) was due to the temporal spacing between paintings, then we would expect that the Temporal Spaced and Interleaved conditions would both be superior to the Massed condition. We had no strong prediction for the Simultaneous Massed condition except that perhaps having multiple paintings by a given artist presented at once may facilitate the abstraction of commonalities, which in turn might benefit induction. Also, if spacing truly promotes inductive learning (and not just memory for the association between a given painting style and the name of the artist), then we should still observe an advantage of spacing when the number of painting styles to be learned is much smaller. In the present study, we used paintings by three different artists (cf. 12 artists in Kornell & Bjork, 2008).

Method

Subjects
Eighty-eight undergraduates from the University of California, San Diego Psychology Subject Pool participated for course credit.

Materials
Forty paintings each by Jan Blencowe, Richard Lindenberg, and Rae O'Shea were used in this study—24 paintings by each of the three artists were randomly selected for each subject for presentation during the study phase, with the remaining 16 reserved for the test phase. All the paintings depicted natural landscapes (see Figure 1 for examples of the paintings). The artists were selected based on the following: (1) their relative obscurity to the average college student (none of our subjects reported being familiar with the work of any of the artists) and (2) their relative similarity in painting styles and subject matter (in order to make the learning task challenging). The paintings were cropped to remove any extraneous clues to the artist's identity (e.g. the artist's signature) and resized to 15 × 11 cm.

Design
Study condition (four levels: Massed, Interleaved, Temporal Spaced, and Simultaneous Massed) was manipulated between subjects (21 to 23 subjects in each condition).

Procedure
Subjects were seated at computer terminals and informed that they would be presented with paintings by three different artists and that their task was to learn to recognize the style of each artist. They were informed that later on in the session they would be tested by being shown previously unseen paintings by the same three artists and being asked to identify which artist painted these novel artworks. Subjects were randomly assigned to one of four study conditions. A schematic of the sequence of paintings for the different study conditions is provided in Figure 2. In the Massed and Interleaved conditions, the study phase consisted of 72 paintings presented one at a time in the center of the screen for 5 seconds each, with a 0.5-second blank screen after each painting. The last name of the artist appeared directly below each painting. The difference was that in the Massed condition, the paintings were blocked by artist, with the ordering of artists randomly determined for each subject; whereas in the Interleaved condition, the sequence of paintings cycled through the three artists (e.g. ABCABCABC, etc.), with no two paintings by the same artist appearing consecutively. In the Temporal Spaced condition, the sequence of paintings was identical to that in the Massed condition (i.e. paintings were blocked by artist), except that the presentation of each painting was followed by (1) a 0.5-second blank screen, (2) a cartoon drawing for 10.5 seconds, (3) a 0.5-second blank screen, then (4) the next painting. Subjects in this condition were told that they would not be tested on the cartoon drawings and did not have to pay attention to them. In the Simultaneous Massed condition, the paintings were presented four at a time (instead of singly) for 20 seconds, with a 2-second blank screen after each set of four. The paintings were blocked by artist, not only in terms of each set of four (i.e. all paintings in a set were by the same artist) but also in terms of the sequencing of the sets (i.e. six sets of four paintings by one artist were presented first before six sets of four paintings by the second artist, and then finally six sets of four paintings by the third artist). Again, the ordering of the artists was randomized for each subject, and the artist's last name accompanied each set of paintings. The entire study phase took about 6.5 minutes for the Massed, Interleaved, and Simultaneous Massed conditions and almost 20 minutes for the Temporal Spaced condition. The average presentation duration of each painting was, however, equivalent across conditions (i.e. 5 seconds).

After the study phase, subjects viewed a ~20-minute video clip (unrelated to the artists/paintings) as a time-filler task, followed by a transfer test on their ability to identify new paintings by the same three artists they were exposed to in the study phase. This was a self-paced test consisting of 48 previously unseen paintings, 16 by each of the three artists, presented one at a time in the center of the screen. The order of paintings was randomly determined for each

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Figure 1. Examples of paintings used in this study. The artist who painted the top, middle, and bottom paintings were Jen Blencowe, Richard Lindenberg, and Rae O'Shea, respectively

subject. Subjects used a mouse to click on the last name of the artist who they thought painted the painting (i.e. three-alternative forced choice). No feedback was provided. After completing the test, subjects were debriefed and thanked for their participation.

Results and discussion

Figure 3 shows mean performance on the final transfer test as a function of study condition. The Interleaved condition yielded the best performance, relative to the other three conditions (which were fairly equivalent). This observation was supported by a one-way analysis of variance (ANOVA) [F (3, 84) = 3.067, MSE = 0.036, partial $\eta^2 = 0.099$] (the α level for all analyses was set at .05). Pairwise comparisons between the conditions confirmed that performance in the Interleaved condition was significantly higher than in each of the other three conditions (ts > 2.48, ds > 0.78), whereas differences among the other three conditions were not reliable (ts < 1).

The results confirm Kornell and Bjork's (2008) findings and show that they generalize to situations in which the memory load is low (i.e. lesser need to remember pairings between category labels and their referents). They also indicate that increasing the temporal spacing between paintings alone was not sufficient to improve induction. To rule out the possibility that the relatively longer study phase for the Temporal Spaced condition may have been a factor, we compared categorization accuracy for the artist presented first and the artist presented third in the study phase. There was no reliable difference in performance (t < 1), suggesting that the difference in test delay was not responsible for the lack of improvement in induction (relative to Massed presentation). Also, facilitating the detection of similarities across paintings by a given artist (i.e. by presenting multiple paintings by the same artist) did

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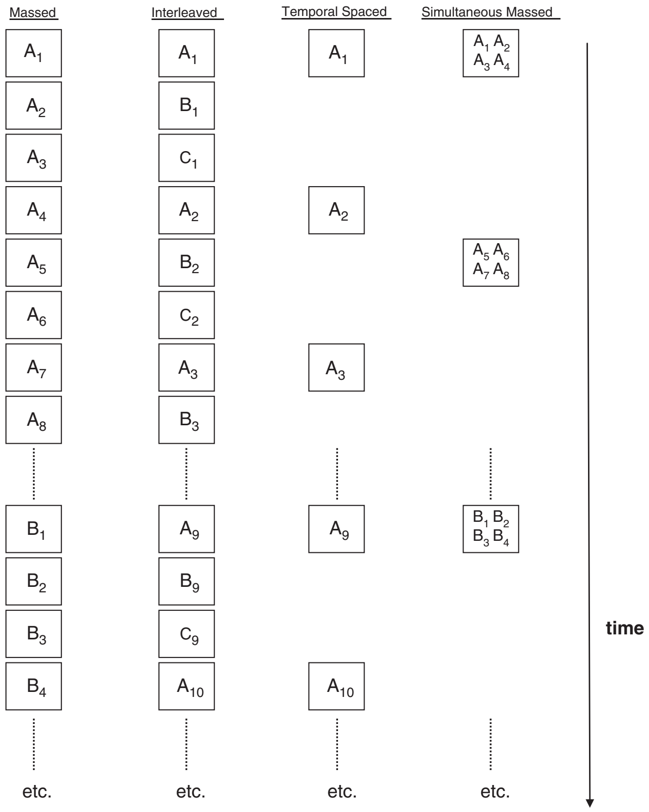

Figure 2. Sequence of paintings during the study phase for the different study conditions in Experiment 1. Letters denote a particular artist, and subscript numbers denote a particular painting by the artist. The order of the specific paintings and artists was randomly determined for each subject, within the constraints of the assigned study condition

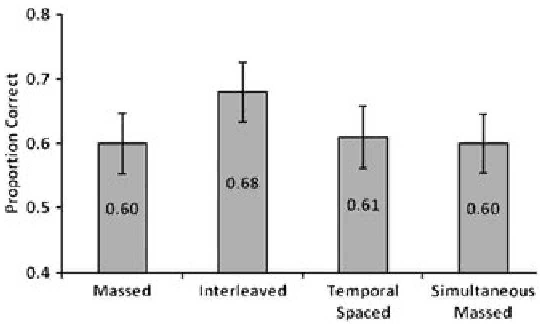

Figure 3. Mean test performance as a function of study condition in Experiment 1. Error bars indicate 95% confidence intervals. Means for each condition are listed within the respective bars

not provide any benefit. Only when the paintings by the three artists were interleaved during study was learning enhanced. This result is consistent with the idea that the key to improving induction when the categories are hard to discriminate may lie in promoting the detection of differences or points of contrast separating the categories.

EXPERIMENT 2

The previous experiment demonstrates that the critical factor that enhanced learning of the artists' styles was not the temporal spacing of the paintings during study but rather the interleaving of paintings by different artists. One likely possibility is that interleaving confers an advantage to perceptual category learning because the presentation of exemplars from different categories in immediate succession facilitates the apprehension of points of contrast separating the exemplars, making these differences among the categories more salient (e.g. Goldstone, 2003; Goldstone & Steyvers, 2001). If this were indeed the case, then one would expect that category learning might benefit from other order manipulations designed to enhance this form of discrimination learning. To test this possibility, in our second experiment, we included a study condition that presented simultaneously paintings by the different artists (*Simultaneous Different*). The juxtaposition of paintings by different artists, even in the absence of temporal spacing, should enhance induction learning as much as interleaving does. One might even hypothesize that having the paintings from each artist be visible simultaneously during study would be more advantageous than interleaving because the former method does not need to rely on memory for previously viewed paintings in order to notice the differences among the artists (cf. Lipsitt, 1961; North & Jeeves, 1956). Also, fewer paintings were used during the study phase in the present experiment to assess whether the advantage of interleaving would be robust even when there was exposure to fewer exemplars during learning.

Method

Subjects

Ninety undergraduates from the University of California, San Diego Psychology Subject Pool participated for course credit.

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Materials

The same materials were used as in Experiment 1, except that in the present experiment 10 paintings by each artist were randomly selected for presentation during the study phase, whereas the remaining 30 paintings by each artist were assigned to the test.

Design

Study condition (three levels: Massed, Interleaved, and Simultaneous Different) was manipulated between subjects with 30 subjects randomly assigned to each condition.

Procedure

The procedure for the Massed and Interleaved study conditions was identical to that in Experiment 1, except that (1) the inter-stimulus interval between paintings was 1 second, (2) 10 paintings by each artist were presented, and (3) each painting was presented twice. Specifically, in the Massed condition, the 10 paintings by a given artist would be presented one at a time in a consecutive sequence and then presented again (in a new random order) before the paintings by the next artist would be presented. In the Interleaved condition, after all 30 paintings were presented in an interleaved sequence, they were re-presented in a new random order (while preserving the interleaving of artists). In the Simultaneous Different condition, paintings were presented in sets of three (one by each artist), with one painting appearing in the upper central part of the screen, another appearing in the lower left, and the third appearing in the lower right. Each set was presented for 15 seconds, followed by a 3-second blank screen. Once all the paintings (10 sets in total) were presented, the order of the paintings was randomized, and the paintings presented again in sets of three. Each painting was accompanied by the artist's last name directly below it. Also, the position on the screen for each artist's paintings was randomly determined for each subject but remained the same for that subject for the entire study phase (e.g. if a painting by Lindenberg appeared in the lower left part of the screen on the first study trial, then for the remainder of the study trials, the lower left part of the screen would be occupied by Lindenberg's paintings).

Subjects in all conditions viewed a ~20 minute video clip after the study phase, followed by a self-paced test. On the test, subjects were presented with 90 previously unseen paintings by the same three artists and had to identify who among the three they thought was the artist of each painting (three-alternative forced choice). No feedback was provided.

Results

Mean test performance across the three conditions is shown in Figure 4. As can be seen from the figure, the Simultaneous Different condition produced the best performance, followed closely by the Interleaved condition, with the Massed condition in last place. An ANOVA confirmed that performance across the conditions was not equivalent [F (2, 87) = 5.174, MSE = 0.076, partial $\eta^2 = 0.106$]. Paired comparisons indicated that the Simultaneous Different condition yielded significantly better learning than the Massed condition [$t(58) = 2.94$, $d = 0.78$] as did the Interleaved condition [$t(58) = 2.15$, $d = 0.56$]. However, the difference between the Simultaneous Different and Interleaved conditions was not reliable ($t < 1$).

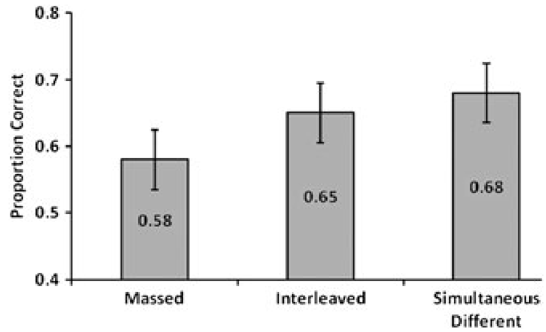

Figure 4. Mean test performance as a function of study condition in Experiment 2. Error bars indicate 95% confidence intervals. Means for each condition are listed within the respective bars

These results provide additional support for the notion that inductive learning of painting styles is facilitated when the differences between the artists' styles are highlighted, whether by interleaving paintings of the various artists during study or by allowing the simultaneous viewing of paintings painted by different artists.

GENERAL DISCUSSION

Kornell and colleagues (Kornell & Bjork, 2008; Kornell et al., 2010) found that inductive learning of artists' styles was better when presentation of paintings at study was spaced (interleaved) rather than massed. The present experiments replicate their findings in contexts in which a small number of more similar painting styles are being learned. In addition, the results go some way toward clarifying the locus of the spacing effect. Specifically, our results indicate that the spacing advantage observed in the learning of painting styles is not due to the temporal spacing of paintings during study but rather to the interleaving of different artists' paintings. Experiment 1 showed that inserting temporal spacing between study trials by itself did not improve learning relative to massed presentation. Experiment 2 demonstrated that viewing simultaneously paintings by different artists produced at least as much benefit as interleaving did, providing further evidence that facilitating discriminative contrast among categories (or artists' styles) is vital to improving induction.

These findings dovetail well with recent research in perceptual discrimination learning. A robust phenomenon from that literature is the *intermixed-blocked effect*—i.e. intermixed exposure to two similar stimuli produces better discriminability of those stimuli on a later test than if the two stimuli were exposed in separate blocks (e.g. Lavis & Mitchell, 2006). A recent study by Mitchell, Nash, and Hall (2008) showed that the intermixed advantage was due to increased opportunity to compare the two similar stimuli (relative to blocked exposure) instead of temporal spacing. Subjects were pre-exposed to similar 20×20 colored checkerboards that differed only in terms of the color and location of six (out of 400) squares, after which they were

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presented with pairs of the checkerboards, presented briefly one checkerboard at a time, and asked to judge whether each pair was the same or different. Discrimination of different checkerboards was much better when pre-exposure to the stimuli was intermixed than when it was blocked. However, when pre-exposure to the stimuli was blocked but with a temporal delay inserted between each stimulus, there was no improvement to later discrimination performance.

It is possible that study conditions that facilitate discriminative contrast promote induction learning only when the categories are very similar and hard to differentiate. Indeed, the paintings we used in our study depicted very similar scenes and, to the untrained eye, seemed very similar in style across the three artists. Previous studies that found an advantage of massing tended to use simpler, contrived stimuli (e.g. Kurtz & Hovland, 1956), and it could be that under those circumstances noticing a few similarities across exemplars within a category is sufficient to allow classification of new examples.

Clearly, the landscape paintings used in the present study were rich, complex stimuli that contained a multitude of features and dimensions, many that were common or overlapping across artists and some that were unique or nonoverlapping. The former are irrelevant to the category discrimination task, whereas the latter are relevant. The critical determinant of successful induction in this case, then, is learning which features should be attended to and which should be disregarded (cf. Mackintosh, 1965). The conditions that produced superior category learning in the present study likely facilitated (i) attention to the features of each stimulus that helped discriminate one category (or artist) from another and/or (ii) greater differentiation on the dimensions on which the categories (or artists) varied (e.g. Goldstone & Steyvers, 2001; Nosofsky, 1986). The present findings with complex, ecologically valid material give us some confidence that the advantage of interleaving will generalize to most kinds of challenging perceptual inductive learning in the real world, where category boundaries are often not obvious and distinguishing among categories is difficult (e.g. learning to spot a cancerous from a non-cancerous mole, differentiating among bird species/subspecies, etc.).

From a theoretical standpoint, how should we interpret the lack of any detectable effect of temporal spacing on this task, as compared with, for example, a paired-associate learning task that would be expected to show robust spacing effects (Cepeda et al., 2006)? One interpretation, of course, would be that category learning reflects the operation of a different system and is for that reason subject to different laws. However, even if one supposed that a common associative mechanism were responsible for both kinds of tasks, there are important differences between what counts as a 'repetition' in the two situations. For one thing, in the Temporal Spaced condition of Experiment 1, the repeated elements were not identical tokens but rather different paintings by the same artist. Thus, this does not correspond closely to the repetition of a stimulus–response pair in a paired-associate task (it is more analogous to the presentation of multiple pairs with different stimulus terms but sharing the same response term). Even in the paired-associate realm, one would probably not expect to observe spacing effects when the pairs are not repeated intact.

Practical implications

We think that our findings have implications not just for the learning of art styles but also for the learning of complex categories found in the real world. We suspect that when people go about learning these categories, it is often the case that they will choose to view exemplars grouped by similarity or category (rather than intermix exemplars from different categories) because the relative fluency of processing gives the illusion that learning is more effective with a massed/blocked strategy (Kornell & Bjork, 2008; McCabe, 2011). Even if learners do not deliberately make this choice, it is likely that training materials are structured in such a way that learners will be successively or simultaneously exposed to exemplars from within a category.

Our informal survey of several medical textbooks (on dermatological and radiological diagnoses) and guidebooks on bird watching and butterflies revealed that the pictorial content of the books did indeed conform to the just-mentioned structure. For instance, Orr and Kitching's (2010) guide to Australian butterflies contains numerous pictures of butterflies throughout the book, but all the pictures are grouped according to butterfly subfamily or genus (see also Glassberg, 2001; Heath, 2004). Similar pictorial organization can be found in guidebooks on birds (e.g. Peterson, 1990; Sibley, 2003). Likewise, in Habif's (2010) clinical dermatology textbook, the description of each skin disorder is accompanied by photographs of real examples, but again multiple exemplars of the same specific disorder are presented together (see also Mergo, 2002, for an example of a chest radiology textbook).

Of course, one could argue that organizing the material in such a manner is simply unavoidable because a guidebook without a topical organization would appear haphazard and unappealing to readers. Although we do not dispute this sentiment, our findings suggest a straightforward practical improvement to these instructional books if one of the pedagogical aims is perceptual category learning—i.e. the inclusion of an additional section devoted to simultaneous depictions of exemplars from different categories on the same page (or on consecutive pages) so that readers can conveniently compare across categories and reap the benefits for inductive learning.

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