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The Role of Bottom-Up vs. Top-Down Learning on the Interleaving Effect in Category Induction

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ABSTRACT

Interleaving has been shown to promote inductive category learning compared to massing. Interleaved presentation allows for the identification of features that are different between categories, thus enhancing discrimination learning of categories, whereas massed presentation promotes identification of features that are common among stimuli from the same category. Previous studies that found the interleaving effect employed the "bottom-up" learning approach (i.e. learning through exposure to exemplars) to inductive category learning. It is not known whether the same effects of interleaving can be observed in category induction using the top-down learning approach (i.e. learning when explicit information about the categories and the experimental procedures involved is given in advance). Thus, it would be interesting to compare "bottom-up learning" and "top-down learning" of categories. Using paintings from several artists, the present study investigated the effect of "bottom-up" learning (i.e. learning through exposure to exemplars) versus "top-down" learning of categories. One hundred and twenty undergraduate students participated in the present study, which used a 2 (Presentation style: Massed vs. Interleaved) x 2 (Learning type: Bottom-up vs. Top-down) mixed-factorial design. Consistent with previous findings, the benefits of interleaving were achieved using the "bottom-up" condition, while the current study also achieved some positive outcomes using the "top-down" condition. However, no significant effect of learning type was found, which indicates that performance in both groups did not differ significantly. Participants in both learning conditions perceived massing to be more helpful to learning than interleaving although their actual performance showed the opposite.

Keywords: Interleaving effect, inductive learning, category learning, category induction, bottom-up learning, top-down learning

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INTRODUCTION

Inductive learning is commonly referred to as the process of learning by examples, during which one makes an inductive inference of a general conclusion from the observed examples. This particular form of learning is often associated with the more general, common definition of induction. In their influential book on induction, Holland, Holyoak, Nisbett and Thagard (1986) defined induction as "all inferential processes that take place in the face of uncertainty" (p.1). Induction is used in everyday life, for instance, to make predictions and choices based on observation or provided facts. Induction is also utilised to discover something new. For example, in science, induction is the basic procedure followed to make scientific discoveries, and this is achieved by making systematic observations, which can include observations of a real event or phenomenon and observations from laboratory experiments.

Recently, the interleaving effect has become the subject of interest among cognitive and educational psychologists with a growing number of researchers documenting the benefits of the interleaving effect in inductive learning, in particular, category learning (i.e. Kornell & Bjork, 2008; Vlach, Sandhofer, & Kornell, 2008; Kornell, Castel, Eich, & Bjork, 2010; Wahlheim, Dunlosky, & Jacoby, 2011; Zulkiply, Kang & Pashler, 2012; McLean, Burt & Bath, 2012). The interleaving effect refers to situations in which memory for categories or concepts is enhanced when exemplars from a particular category are juxtaposed or interleaved with exemplars from other categories, rather than when the exemplars from several categories are massed throughout.

In category learning, induction is the kind of reasoning that one uses when drawing conclusions about the category in general (Murphy, 2002). For instance, a typical experiment that examines an interleaving effect in category learning began with a study phase, during which participants were presented with exemplars from several categories. Some of the categories were interleaved, that is, exemplars from several categories were presented with lapses in time, by incorporating them with exemplars from other categories (e.g. Kornell & Bjork, 2008; Kornell *et al.*, 2010). On the other hand, others are massed i.e. exemplars from several categories were presented contiguously. Later, in the test phase, each participant's category induction was tested. This is accomplished (using corrective feedback) by asking each participant to classify individual exemplars into one of the contrasting categories (Bruner, Goodnow, & Austin, 1956; Posner & Keele, 1968; 1970; Medin & Schaffer, 1978). This type of experimental task is a form of discrimination learning (Clapper, 2007) and it is often referred to as classification learning in the category learning literature.

A few earlier studies showed that massing facilitates induction (e.g. Gagne, 1950; Kurtz & Hovland, 1956; Whitman & Garner, 1963). Nevertheless, there is growing evidence from recent research suggesting that interleaving results in superior learning of categories and concepts (i.e. Kornell & Bjork, 2008; Vlach *et al.*, 2008; Kornell *et al.*, 2010; ahlheim *et al.*, 2011; Kang & Pashler, 2012; WZulkiply *et al.*, 2012, Zulkiply & Burt, 2013a). Stimuli used in investigating the interleaving effect in category learning research have included numerous materials such as paintings from several artists (e.g. Kornell & Bjork, 2008, Kornell *et al.*, 2010; Kang & Pashler, 2012), different categories of bird families (e.g. Wahlheim *et al.*, 2011), textual materials (Zulkiply *et al.*, 2012) and different categories of novel objects that were constructed from arts and craft supplies and objects from hardware stores (e.g. Vlach *et al.*, 2008). In addition, the interleaving effect has been found in the short-term retention condition (e.g. Kornell & Bjork, 2008; Vlach *et al.*, 2008; Kornell *et al.*, 2010; Wahlheim *et al.*, 2011) and in the long-term retention condition (e.g. Zulkiply & Burt, 2013b).

Despite the fact that there is growing evidence in the existing literature that induction profits from interleaving (rather than massing) in category learning, the effect of interleaving on "bottom-up" versus "top-down" learning of categories is not clear. Thus, it would be interesting to compare "bottom-up learning" and "top-down learning" of categories. In "bottom-up" learning, the "big picture" (the explicit information and process involved) is not given in advance to the learners at the beginning of the study session, thus requiring them to learn the information in a logical manner and then construct knowledge from the basics to obtain the "big picture". In contrast, in "top-down" learning the "big picture" is provided first. In the present study context, "bottom-up" learning of categories referred to learning through exposure to exemplars as in induction, whereas "top-down" learning referred to learning when explicit information about the categories and the details of what was involved in the experiment (process) were given to students prior to giving them the exemplars.

Previous studies that confirmed the benefits of the interleaving effect in induction category learning have employed "bottom-up" learning, where students learnt the categories before they started the study phase, solely by exposure to exemplars and without receiving explicit information about the categories (i.e. the types of category and the process involved) (Kornell & Bjork, 2008; Vlach *et al.*, 2008; Kornell *et al.*, 2010; Wahlheim *et al.*, 2011; Zulkiply *et al.*, 2012). The effect of interleaving on "top-down" learning of categories is unknown, thus it will be interesting to discover whether the benefits of interleaving in induction category learning using "top-down" learning will be upheld. The latter method may be more efficient because of the clarity of the explicit knowledge provided in the instructions given at the beginning of the learning process. It has been argued that both bottom-up (perceptually driven) and top-down (conceptually driven) are processes involved in adult categorisation (French, Mareschal, Mermillod, & Quinn, 2004), and that they are deeply intertwined, thus isolating and studying them independently are not easy to perform (Goldstone & Barsalou, 1998). In the present study design, the variable learning type (bottom-up vs. top-down) was a between-subjects factor, thus it was possible to examine the two processes independently, particularly to investigate which process was most effective in promoting inductive category learning. Furthermore, since the learning of any possible sets of categories could be done implicitly (bottom-up) or explicitly (top-down) as in the present study, it is beneficial to understand how each process (bottom-up vs. top-down) affects the interleaving and massing categories and to examine which one of the two presentation types (interleaved vs. massed) facilitates better learning of categories.

The main objective of the present study was to examine the effect of “bottom-up” versus “top-down” learning of categories on the interleaving effect. The present study focused on the following research question, “What effect does ‘bottom-up’ versus ‘top-down’ learning of exemplars have on the interleaving effect?” Category learning is a common and essential approach used in many subjects taught at school, college and university. Inductive learning is one of the many means that can be used to teach and learn categories; thus, it would be worthwhile to understand how “bottom-up” versus “top-down” learning affects inductive learning or category learning under massed and interleaved learning conditions. The findings from the present study could advance knowledge of the interleaving effect in induction category learning as well as contribute to the theoretical foundations of the effect of interleaving on inductive learning, particularly in the issue of “bottom-up” versus “top-down” learning of categories. In addition, previous studies that used a “bottom-up” learning approach (e.g. Kornell & Bjork, 2008; Kornell *et al.*, 2010; Zulkiply *et al.*, 2012; Zulkiply & Burt, 2013a) found that although participants’ performance was superior in the interleaved condition, the majority of subjects perceived that massing was the more effective presentation style which had aided them in the learning process. The present study investigated whether the same judgement pattern existed in the “top-down” learning condition.

METHOD

The present experiment examined the effect of “bottom-up” versus “top-down” learning of exemplars on the interleaving effect.

Participants and Design

The participants were 120 undergraduate students (78 females, 42 males). The experiment used a 2 (Presentation style: Massed vs. Interleaved) x 2 (Learning type: Bottom-up vs. Top-down) mixed-factorial design. Learning type was varied between-subjects, while presentation style was varied within-subjects.

Materials

The materials used in this experiment were taken from the Kornell and Bjork (2008) study and consisted of 120 paintings showing skyscapes or landscapes from 12 different artists: Judy Hawkins, George Wexler, Yie Mei, Bruno Pessani, Georges Braque, Philip Juras, Georges Seurat, Marilyn Mylrea, Ron Schlorff, Ciprian Stratulat, Ryan Lewis and Henri-Edmond Cross. As noted, 72 paintings were used in the presentation/study phase (six paintings per artist), and the paintings were arranged in 12 learning blocks (six blocks of massed presentation, six blocks of interleaved presentation). The order of the blocks was MIIMMIIMMIIM (M for massed; I for interleaved). Another 48 paintings were used in the test phase (four paintings per artist). The paintings were in the format of JPEG files and were resized to fit into a 17 cm x 27 cm rectangle on the computer screen.

Procedure

Participants were randomly assigned to either the "bottom-up" learning condition or the "top-down" learning condition. The experimental manipulation had four steps: presentation (study) phase, distractor task phase, test phase and question phase. In the presentation phase, participants were asked to study the 72 paintings by the 12 artists. Each painting was shown on a computer screen for 3 seconds, with the last name of the artist displayed underneath. In addition to this brief instruction, participants in the "top-down" learning condition were given additional information in advance i.e. before they started to learn the paintings. This information included the name of the 12 artists, the fact that the artists had distinctive painting styles and the remaining experimental procedures that they would be undergoing next. In particular, when participants studied the paintings, they were asked to learn to associate each artist with his/her picture, based on the artists' style. They were also told that they would be given a test later, in which their induction would be assessed on a series of novel paintings by the 12 artists they had learnt in the study phase. They were further informed that in the test phase, for each trial they would be asked to click their computer mouse on one of 13 buttons provided (12 of the buttons were labelled with the name of the artists and one was labelled "I don't know"). Participants were also informed that some of the artists were going to be "Massed" (whereby all paintings by an artist were presented consecutively), and that some of the artists were going to be "Interleaved" (whereby paintings by an artist were interleaved/ juxtaposed with other artists' paintings), and finally, at the end of the experiment, that they would be asked to indicate which condition they thought provided the most assistance to their learning (i.e. massed presentation or interleaved presentation). This detailed information was not given in advance to the participants in the "bottom-up" learning condition.

After the study phase was concluded, participants in both learning conditions were asked to complete a distractor task, during which they were asked to count backwards by 3s starting from 715, for 15 seconds, while typing the numbers in the designated box on the computer screen.

In the test phase, the 48 new paintings by the artists (four new paintings by each of the 12 artists) were presented in a fixed order across all participants. Participants were shown one painting at a time on the computer screen, with the same 13 buttons below the painting, and were required to identify the artist. Participants responded according to who they thought had created each painting by clicking the computer mouse on the corresponding artist's button or if unknown, clicking on the "I don't know" button. Feedback was given immediately after each response. If participants responded correctly, the word 'correct' would appear on the computer screen. If they responded incorrectly, the correct artist's name would be displayed. Participants completed the test phase at their own pace. After the test phase, participants were informed of the meaning of the terms 'massed' and 'interleaved' via a description displayed on the computer screen. They were then asked the following question: 'Which option do you think helped you learn more?' and were provided with three possible answers: 'massed', 'about the same', or 'spaced'. The question phase ended the experimental manipulation. No time limit was applied to the response stage in the experiment.

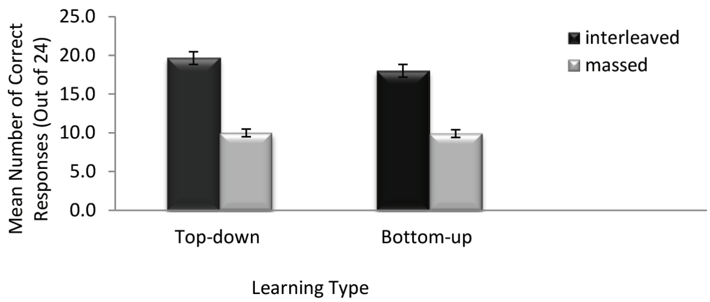

Fig.1: Mean number of artists selected correctly. Results are arranged by presentation style (interleaved or massed) and learning condition (top-down or bottom-up). Error bars represent standard errors.

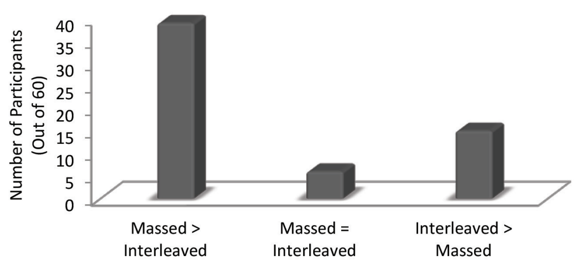

Fig.2: Number of participants who judged massing to be more effective than, equally effective as or less effective than interleaving in the "bottom-up" learning condition.

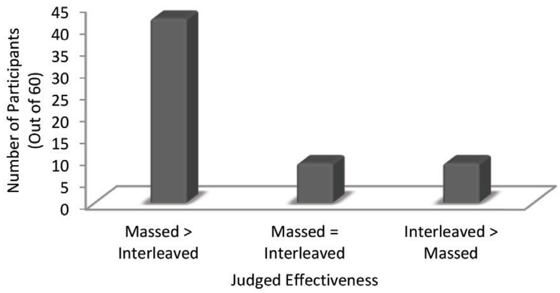

Fig.3: Number of participants who judged massing to be more effective than, equally effective as or less effective than interleaving in the "top-down" learning condition.

RESULTS

The data from the experiment were analysed using a two-way mixed ANOVA statistical test. As shown in Fig.1, there was a significant effect of presentation style, $F(1,118)=87.88$, $p<0.001$, $\eta p2=0.43$ indicating that interleaved presentations resulted in more learning than massed presentations regardless of the learning type factor, that is, whether the participants studied in the "bottom-up" or the "top-down" learning condition. However, the main effect of learning type ("bottom-up" or the "top-down") was not significant, $F(1,118)=0.48$, $p=0.49$, suggesting that there is no significant difference in performance between the two learning conditions. Additionally, the interaction between presentation style and learning type was not significant, $F(1,118)=0.77$, $p=8.38$, suggesting that the benefit of interleaving was equivalent in both learning conditions (i.e. the benefit of interleaving was not dependent on whether the participants had participated in the "bottom up" condition or the "top-down" condition).

With regards to participants' judgement of which study presentation helped them learn more, a similar preference for massed presentation was expressed in both learning conditions when, in reality, interleaving was actually more effective for the majority of them (see Fig.1). A one-way Chi-square analysis was conducted to compare the proportion of participants who judged massed to be more useful with the proportion of participants preferring interleaved and the proportion judging that the two conditions contributed equally in helping them to learn more during the study phase. As predicted, the result for the "bottom-up" learning condition was consistent with previous findings (e.g. Kornell & Bjork, 2008; Kornell *et al.*, 2010), $\chi2(2,N=60)=7.70$, $p=0.042$. In terms of judged effectiveness, of a total of 60 participants, a majority of 39 (65%) claimed that massed presentation was better, 15 (25%) preferred interleaved while six (10%) judged that both massed and interleaved presentations contributed equally to their learning during the learning phase, regardless of their performance under the two conditions i.e. massed and interleaved (see Fig.2). In terms of actual effectiveness, 42 (70%) of participants performed better in the interleaved condition, 12 (20%) performed better in the massed condition while 6 (10%) performed equally in the two conditions.

In the "top-down" learning condition, a similar pattern of judgement was observed, $\chi2$ (2, *N=60*)=4.43, *p*=0.023. In terms of judged effectiveness, of a total of 60 participants, a majority of 42 (70%) participants claimed massed was more effective, nine (15 %) claimed interleaved and another nine (15%) judged the two conditions to be equally effective regardless of their performance in the two conditions i.e. massed and interleaved (as shown in Figure 3). In terms of actual effectiveness, 45 (75%) of the participants performed better in the interleaved condition, 12 (20%) performed better in the massed condition and three (5%) performed equally in the two conditions. The massed presentation of categories (as compared to the interleaved presentation) may be perceived as being easier by the participants because it created a sense of familiarity for each category, which later guided them to conclude that massed presentation was more helpful (Zulkiply & Burt, 2013a). It can be argued that the impressions, intuitions and feelings that guide us are not always justified and we are often confident even when we are wrong (Kahneman, 2011).

DISCUSSION

Parallel with the findings from past studies (e.g., Kornell & Bjork, 2008; Kornell *et al.*, 2010; Zulkiply *et al.*, 2012), the present study denoted the benefits of the interleaved presentation of categories in the "bottom-up" learning condition. Interestingly, the benefits of interleaving were also observed in the "top-down" learning condition i.e. participants correctly classified more novel paintings from the artist categories that were presented in the interleaved manner during the study or presentation phase when compared to the novel paintings from the artist categories that were massed.

The superior performance in the interleaved condition over the massed condition could be caused by a number of factors. The primary factor concerned the role of interleaving itself in enhancing discrimination learning (e.g. Kornell & Bjork, 2008; Zulkiply & Burt, 2013a). In an interleaved presentation, exemplars of several categories were mixed, in particular the exemplars from a particular category were juxtaposed with exemplars from other categories. This type of presentation allows paintings from several different artists to be displayed on the computer screen sequentially, giving the participants an opportunity to compare and contrast the paintings that are different, based on the different styles of the artists and thereby fostering discrimination learning. It is argued that the interleaved presentation encouraged the capturing of points of contrast among exemplars from several categories, thus highlighting these differences and making them noticeable (e.g. Goldstone, 2003; Carvalho & Goldstone 2012; Kang & Pashler, 2012). On the other hand, the massed presentation promoted the recognition of features that were characteristic among exemplars within a single category (Carvalho & Goldstone, 2012).

It is also suggested that the benefits of the interleaving effect in induction category learning is attributable to the advantage received by the interleaved exemplars in terms of attention. Previous studies highlighted the role of allocating one's attention during category learning (Nosofsky, 1986; Kruschke, 1992; Minda & Smith, 2002; Love, Medin, & Gureckis, 2004). The mixing of exemplars of several categories as in the interleaved presentation might have made the learning of the categories more difficult for the participants compared to the massed presentation of exemplars by categories, by affecting the amount of attention given to interleaved and massed exemplars. It is argued that interleaved exemplars received more attention and were processed more deeply than massed exemplars. Exemplars that are presented massed by categories are likely to create a sense of familiarity in participants, thus reducing the amount of attention participants pay to them, which possibly might have impeded learning (e.g. Wahlheim *et al.*, 2011; Zulkiply & Burt, 2013a).

In terms of the effect of learning type, performance in the "top-down" learning condition was not significantly different from performance in the "bottom-up" condition. It seems that clarity of the explicit knowledge in the instructions provided to the participants in the "top-down" condition, and the assumed benefit of these in terms of preparedness for the experiment to follow were not found to be significantly helpful in the present category induction experiment. Nevertheless, a slightly better learning for the interleaved categories in the "top-down" condition (M=20.8) compared to the "bottom-up" condition (M=19.1), as depicted by the mean test accuracy for the two learning conditions, suggested that participants in the "top-down" condition perhaps gained little benefit from using that particular learning condition. As noted, in the "top-down" condition, participants were given the name of the 12 artists and were told that the artists had distinctive painting styles. Had the explicit information included an example of a painting from each of the artists, the performance in the "top-down" condition may have been improved. Consequently, it would be interesting to examine the effect of the different levels of "top-down" instruction (e.g. deep vs. superficial) on the interleaving effect in category induction. A slightly lower performance in the "bottom-up" condition compared to the "top-down" condition in the current category induction experiment seems to suggest that in category induction, "bottom-up" learning may have resulted in the learning of the categories being more difficult due to the unavailability of the crucial explicit information about the categories and other processes involved in the experiment. On the other hand, it is also possible that it caused participants to generate more mental effort during the learning process. Though it is not significantly evident in the present study, there is a likelihood that in some situations, the difficulty introduced by the "bottom-up" learning, particularly in the category induction experiment, contributed to producing better learning and understanding of the different categories. This issue warrants further investigation.

CONCLUSION

The findings of the present study could provide insight to educators on factors that should be considered in designing and developing a systematic approach to enhance category learning in students. Earlier it was thought that "top-down" learning may be more efficient than "bottom-up" learning because the clarity of the explicit knowledge provided in the instructions given at the beginning of the learning process is likely to be of advantage; however, the present study indicated that "bottom-up" learning could provide similar results; thus, the potential benefits that induction from exemplars could offer should not be overlooked. "Bottom-up" learning from exemplars may be difficult, perhaps because of the unavailability of the systematic and explicit definitions of the 'to-be-learnt' categories which help to facilitate induction from examples. Consequently, it may require substantially more mental effort during the learning process, and this kind of learning experience can sometimes produce an equivalent level of category understanding (as compared to "top-down" learning), particularly when using relatively small sample sized categories, as evident in the present study, which used a sample of 12 artists only. Educators may want to incorporate either a "top-down" learning method or a "bottom-up" learning method in teaching small-range categories.

Along these lines, it would be interesting to look into issues that might affect the choice of instructional technique (e.g. When is it best to use "bottom-up" induction or a "top-down" learning approach?). The "bottom-up" learning approach may perhaps work better for small-ranged categories, whereas a "top-down" learning approach may be more effective when the categories are more numerous. It is also possible that both approaches are beneficial in certain situations, and if this is the case, perhaps the best way is to find a balance between these two approaches and create a hybrid approach based on best practices from both strategies. It would be interesting to examine these issues in future research.

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REFERENCES

Bruner, J. S., Goodnow, J. J., & Austin, G. A. (1956). *A study of thinking*. New York: Wiley.

Carvalho, P., & Goldstone, R. (2012). Category structure modulates interleaving and blocking advantage in inductive category acquisition. In C. R. P. Miyake, N. D. Peebles. (Eds.), *Proceedings of the 34th annual conference of the cognitive society*. Austin, TX: Cognitive Science Society.

Clapper, J. P. (2007). Category learning as schema induction. In M. A. Gluck, J. R. Anderson, & S. M. Kosslyn. (Eds.), *Memory and mind: A festschrift for Gordon H. Bower*. New Jersey: Lawrence Erlbaum Associates.

French, R. M., Mareschal, D., Mermillod, M., & Quinn, P. C. (2004). The role of bottom-up processing in perceptual categorization by 3- to 4-month old infants: Simulations and data. *Journal of Experimental Psychology: General, 133*, 382–397.

Gagne, R. M. (1950). The effect of sequence of presentation of similar items on the learning of paired-associates. *Journal of Experimental Psychology, 40*, 61–73. doi: 10.1037/h0060804.

Goldstone, R. L. (2003). Learning to perceive while perceiving to learn. In R. Kimchi, M. Behrmann, & C. Olson (Eds.), *Perceptual organization in vision: Behavioural and neural perspectives* (pp. 233-278). Mahwah, NJ: Lawrence Erlbaum Associates.

Goldstone, R. L., & Barsalou, L. W. (1998). Reuniting perception and conception. *Cognition*, *65,* 231–262.

Holland, J. H., Holyoak, K. J., Nisbett, R. E., & Thagard, P. (1986). *Introduction: processes of inference, learning and discovery.* Cambridge, MA: MIT Press.

Kahneman, D. (2011). *Thinking, fast and slow*. New York: Farrar, Strauss and Giroux.

Kang, S. H. K., & Pashler, H. (2012). Learning painting styles: Spacing is advantageous when it promotes discriminative contrast. *Applied Cognitive Psychology*, *26,* 97–103. doi:10.1002/acp.1801.

Kornell, N., & Bjork, R. A. (2008). Learning concepts and categories: Is spacing the "enemy of induction"? *Psychological Science, 19,* 585–592. doi: 10.1111/j.1467-9280.2008.02127.x.

Kornell, N., Castel, A. D., Eich, T. S., & Bjork, R. A. (2010). Spacing as the friend of both memory and induction in young and older adults. *Psychology and Ageing, 25,* 498–503. doi:10.1037/a0017807.

Kruschke, J. K. (1992). ALCOVE: An exemplar-based connectionist model of category learning. *Psychological review*, *99,* 22–44. doi:10.1037/0033-295X.99.1.2.

Kurtz, K. H., & Hovland, C. I. (1956). Concept learning with differing sequences of exemplars. *Journal of Experimental Psychology, 51,* 239–243.

Love, B. C., Medin, D. L., & Gureckis, T. M. (2004). SUSTAIN: A network model of category learning. *Psychological Review*, *111,* 309–332.

Medin, D. L., & Shaffer, M. M. (1978). A context theory of classification learning. *Psychological Review, 85,* 207–238.

Minda, J. P., & Smith, J. D. (2002). Comparing prototype-based and exemplar-based accounts of category learning and attentional allocation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *28,* 275–292.

Murphy, G. L. (2002). *The big book of concepts*. The MIT Press.

Nosofsky, R. M. (1986). Attention, similarity, and the identification-categorization relationship. *Journal of experimental psychology: General*, *115,* 39–57.

Posner, M. I., & Keele, S. W. (1970). Retention of abstract ideas. *Journal of Experimental Psychology, 83,* 304–308.

Vlach, H. A., Sandhofer, C. M., & Kornell, N. (2008). The spacing effect in children's memory and category induction. *Cognition, 109,* 163–167. doi:10.1016 /j.cognition. 2008.07.013.

Wahlheim, C. N., Dunlosky, J., & Jacoby, L. L. (2011). Spacing enhances the learning of natural concepts: An investigation of mechanisms, metacognition, and ageing. *Memory and Cognition, 39,* 750–763.doi:10.3758/s13421-010-0063-y.

Whitman, J. R., & Garner, W. R. (1963). Concept learning as a function of form of internal structure. *Journal of Verbal Learning and Verbal Behaviour*, *2,* 195–202.

Zulkiply, N., McLean, J., Burt, J. S., & Bath, D. (2012). Spacing and induction: Application to exemplars presented as auditory and visual text. *Learning and Instruction, 22,* 215–221. doi:10.1016/j.learninstruc.2011.11.002.

Zulkiply, N., & Burt, J. S. (2013a). The exemplar interleaving effect in inductive learning: Moderation by the difficulty of category discriminations. *Memory and Cognition*, *41,* 16–27.doi: 10.3758/s13421-012-0238-9.

Zulkiply, N., & Burt, J. S. (2013b). Inductive leaning: Does interleaving exemplars affect long-term retention? *Malaysian Journal of Learning and Instruction, 10,* 133–155.