Can You Repeat That?
The Effect of Item Repetition on Interleaved and Blocked Study

Abigail S. Kost (askost@indiana.edu)
Paulo F. Carvalho (pcarvalh@indiana.edu)
Robert L. Goldstone (rgoldsto@indiana.edu)
Department of Psychological and Brain Sciences, Indiana University, 1101 E. 10th Street
Bloomington, IN 47405 USA

Abstract

Three experiments explore differences between blocked and interleaved study with and without item repetition. In the first experiment we find that when items are repeated during study, blocked study results in higher test performance than interleaved study. In the second experiment we find that when there is no item repetition, interleaved and blocked study result in equivalent performance during the test phase. In the third experiment we find that when the study is passive and includes no item repetition, interleaved study results in higher test performance. We propose that learners create associations between items of the same category during blocked study and item repetition strengthens these associations. Interleaved study leads to weaker associations between items of the same category and therefore results in worse performance during test when there are item repetitions.

Keywords: concept learning; sequencing; memory; active study; passive study

Introduction

Flashcards are a popular study tool among students who are preparing for an exam. Flashcards allow students to study several different concepts together in a sequence. Students are able to order the information however they like and can repeat any information as needed. In flashcard study, as in any learning situation that involves the sequential presentation of different types of items, an important pedagogical question is whether the different concepts should be studied separately or intermixed.

This question has been studied before by contrasting interleaved and blocked study. Interleaved study consists of presenting examples of different categories or concepts in close succession. For example, if one wanted to learn about the styles of Monet, Degas, and Renoir through an interleaved presentation, one might study a painting by Monet, a painting by Degas, a painting by Renoir, a painting by Monet, a painting by Degas, a painting by Renoir and so on. Blocked study, on the other hand, consists of presenting examples of the same category or concept in close succession before seeing a different category. To study the same styles in a blocked study, one would see a sequence such as: Monet, Monet, Degas, Degas, Renoir, and Renoir.

The sequence of materials during study is crucial to how well the information is learned. Previous research suggests that interleaving categories maximizes the contrast between items from different categories and enhances discrimination learning (Kornell & Bjork, 2008; Carvalho & Goldstone, 2014; Taylor & Rohrer, 2010). When information is studied in a blocked sequence, on the contrary, contrast between items of the same category is maximized, making similarities among items belonging to the same category more salient (Carvalho & Goldstone, 2014). A similar pattern is found in perceptual learning (Mitchell & Hall, 2014).

To account for this dichotomy, Carvalho and Goldstone (2014) proposed the attentional bias theory. According to this theory the dichotomy between when interleaved and blocked study are beneficial is the result of the same principle: the selective emphasis of categorization-relevant features through comparison of sequentially presented objects. Consistent with the proposals of the attentional bias theory, the relative advantage of interleaved over blocked study has been shown to be moderated by the type of category being studied (Carvalho & Goldstone, 2014, whether study is active or passive (Carvalho & Goldstone, 2015), and the introduction of temporal spacing between category repetitions (Birnbaum et al. 2014). These results present important implications to how students should organize their study. A general proposal is that study sequence could be used to foster learning if effectively selected.

An extension of the attentional bias theory could involve the role of the creation of inter-item associations during study. Because the learner's attention to within-category similarities is maximized during blocked study, this is likely to contribute to a stronger encoding of the similarities and the creation of associations between items that share these common properties. For example, if one is studying three categories in a blocked sequence one might see them as follows: A1, A2, A3, B1, B2, B3, C1, C2, C3. A2 would be associated with A1 and A3 because of their temporal proximity and shared commonalities. By contrast, in an interleaved sequence, items of the same category are not shown temporally close in a sequence and identifying commonalities between them therefore establishing associations between the items of the same category is less likely to occur. Using the same examples as before, an interleaved sequence might look like: A1, B1, C1, A2, B2, C2, A3, B3, C3. Participants would be looking for differences between items of different categories and items of the same category are presented further apart in time.

After reviewing all of the material in a lesson once, students often review the same information again. What is the effect of adding a second review of all of the materials after studying the materials once? If what is encoded and the associations established during the first review of the materials differ between the interleaved and blocked sequences, as we have proposed, then it is likely that a second review would have a differential effect depending on the study sequence.

If item repetition is added later into a blocked sequence the learner might see, for example, A1, A2, A3, B1, B2, B3, C1, C2, C3, A1, A2, A3, B1, B2, B3, C1, C2, C3. When one sees A1 for the second time, one is likely to retrieve A2 and A3 as belonging to the same category as well, because A1, A2, and A3 were strongly associated during the first presentation. If item repetition is added later into an interleaved sequence the learner might see A1, B1, C1, A2, B2, C2, A3, B3, C3, A1, B1, C1, A2, B2, C2, A3, B3, C3. In this sequence, a new occurrence of A1 is less likely to result in the recollection of A2 and A3 because they were not strongly associated during the first presentation.

Another possibility is that, when A1 is repeated in a blocked sequence the commonalities between all A items (A1, A2, and A3 in this example) that were extracted and encoded during the first study of these items will be selectively, and more quickly, reemphasized. Interleaved study, on the other hand, does not allow for the reactivation of commonalities initially identified because learners are unlikely to have noticed communalities between items of the same category during initial study.

In effect, through a process of iterative recollection of previous items (Hintzman, 2010; Ross, 1984; Ross, Perkins, & Tenpenny, 1990), or rapid reactivation of common properties when repetitions are presented, learners in a blocked study sequence recollect more of the items in each category during a second review, contributing to more effective learning in that sequence of study.

In this paper we look at the influence of item repetition on blocked and interleaved study across three experiments. We predict that when item repetition is present, blocked study will result in higher performance during the test phase due to better encoding of the entire category.

Experiment 1

In Experiment 1 learners study the paintings from different artists with six artist options below the painting that they must select from (e.g. active study) and the study sequence is repeated once. We predict that the existence of a repetition of the study sequence will result in better performance following blocked study than interleaved study. As we mentioned in the introduction, we expect that through a process of iterative recollection learners in the blocked study use the repetition to recall more of the items originally associated with the repeated painting.

Method

Participants Forty-eight undergraduate students at Indiana University volunteered to participate for partial course credit. Eight participants were excluded from analyses due to computer error (N=4) or not reaching performance above chance level during either of the study phases (performance below 17%; N=4).

Stimuli and Apparatus The stimuli were 120 paintings by twelve artists (ten paintings by each artist). This set of stimuli has been used in previous studies (e.g., Kornell & Bjork 2008; see Figure 1).

To evaluate previous knowledge, we used a questionnaire containing a list of 36 artists in three categories (famous artists, artists featured in the experiment, and fake, but plausible, artists). Stimuli presentation and participants' responses were collected using E-Prime (Psychology Software Tools, Pittsburgh, PA).

Figure 1: This is an example of 3 paintings from 4 artists that appeared during the experiment. The artist name is listed above each row.

Procedure Participants started by completing the questionnaire. The participants were asked to circle any artist name with which they were familiar. After completing the questionnaire, participants continued to the experiment. There were six phases to the experiment: Study1, Trivia1, Test1, Study2, Trivia2, and Test2. During the study phases a painting would appear on the screen with six artist names (e.g., Bruno Pessani) listed below it. The image would disappear after 1500 ms and participants were asked to click on the artist name that they thought painted the image. Feedback was given after every choice (whether it was correct or incorrect). During the trivia phases, participants answered ten trivia questions. This distractor task lasted approximately three minutes. During the test phases, a painting would appear with the names of the six studied artists below. The participants were instructed to click on the name of the artist who they thought painted the image. Feedback was not provided. Five paintings from each artist were selected to be used during the study phase and five paintings were selected to be used during the test phase. Painting group/phase assignment was counterbalanced across participants.

There were two study conditions. In the blocked study condition participants saw a sequence of paintings such that all paintings from one artist were shown before studying the next artist (for a total of 30 trials). In the interleaved study condition participants saw a sequence of paintings such that no painting from the same artist was shown consecutively (for a total of 30 trials). In both study conditions the sequence was repeated once (for a total of 60 trials) and the order of artists and paintings was fixed across participants. During the test phase the order was fully randomized. Every participant completed both study conditions. The order of the study conditions and artist assignment were counterbalanced across participants.

Results and Discussion

We started by analyzing the data from the questionnaire. The questionnaire was scored in the following way: for every artist included in the experiment correctly recognized, 2 points were added, for every fake artist selected, 1 point was deducted, and for every famous artist selected, 1 point was added, for a total of 24 points. Participants were excluded from analyses if they reached the score of 20 or higher. No participants reached this criterion (M=7.65, SD= 4.08).

Looking at performance during the study phase, we expected that performance in the blocked condition would be higher than in the interleaved condition because if participants choose the strategy of selecting the same artist as on the previous trial, they are more likely to be correct than they would in the interleaved condition. The results show that study performance in the blocked condition is higher (M = 0.68, SD = 0.19) than in the interleaved condition (M = 0.37, SD = 0.11), t (39) = 10.42, $p < .0001$.

Figure 2 shows the results from the test phase. Blocked study results in higher performance during the test phase F (1,39) = 10.98, p = .002, $\eta_G^2 = .059$. Moreover, overall performance is higher for old items compared to novel items, F (1,39) = 5.95, p = .02, $\eta_G^2 = .003$, but there is no interaction between the two variables, $F < 1$.

Contrary to previous evidence from similar studies (e.g., Kornell & Bjork 2008; Kornell, Castel, Eich, & Bjork, 2010; Wahlheim, Dunlosky, & Jacoby, 2011), we found that blocked, relative to interleaved, study results in higher performance during test. The major differences between the current study and past studies are that our study phase was an active learning procedure and there was item repetition.

The verbatim repetition included in this experiment gives learners a second chance to learn each painting with temporal spacing between repetitions (Thios, 1972) and, as we proposed in the introduction, might promote learning by allowing the reactivation of all the items seen before or quicker and more efficient selective activation of the commonalities during study of a repeated item.

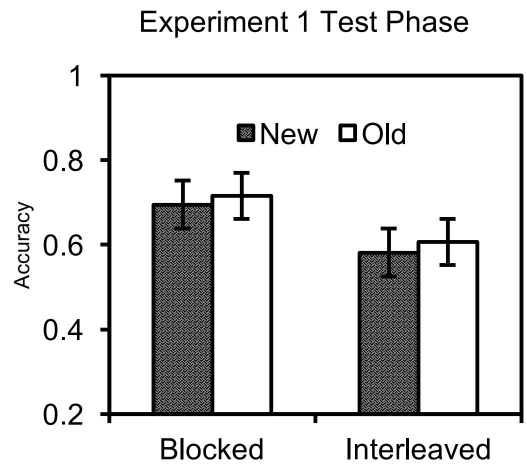

Figure 2: This graph shows performance during the test phase for the blocked and interleaved study conditions for new and old stimuli in Experiment 1. Chance performance in this task is 0.17. Error bars represent standard errors of the mean.

The active learning procedure requires a selection of a response during study, in contrast to previous studies in which the item was presented along with the correct category assignment (passive study). As mentioned in the introduction, it has been shown before that the type of study (active vs. passive) affects whether interleaved or blocked study is more advantageous for learning (Carvalho & Goldstone, 2015) because it changes the constraints of the learning task. However, previous studies have shown that interleaved study benefited learning in an active study task (Carvalho & Goldstone, 2015) contrary to what is seen here. There are several possible reasons for this apparent incongruence: On the one hand it is possible that the greater number of categories and the different type of categories used here might have changed the constraints of active study. In fact, Carvalho and Goldstone (2015) proposed that when using information integration categories (categories for which it is not possible to devise a categorization rule like the ones used in this experiment), the direction of the effect might be reversed. On the other hand, it is possible that the advantage of blocked study seen in this experiment is solely the result of the existence of item repetition during study.

In order to investigate the independent role of repetition, Experiment 2 retains active study of categories but without item repetition during study. In the absence of repetition, there is no occasion for repetition-induced recall during the second study round, as proposed. Therefore, we expect interleaved study to result in better performance than blocked study, as has been shown in previous studies (e.g., Kornell & Bjork, 2008; Kornell et al, 2010).

Experiment 2

Method

Participants Forty-eight undergraduate students at Indiana University volunteered to participate for partial course credit. Seven participants were excluded from data analyses because of prior knowledge of the artists used in the experiment as measured by a questionnaire (N = 1) or not reaching performance above chance level during either study phase (performance below 17%; N = 6).

Stimuli and Apparatus The stimuli were the same as in Experiment 1. The questionnaire was the same as in Experiment 1, except two extra questions were added to assess participants' major and the number of fine art classes taken. Stimuli were presented and participants' responses were collected using E-Prime (Psychology Software Tools, Pittsburgh, PA) as in Experiment 1.

Procedure The procedure was the same as in Experiment 1, except for the following changes. Participants studied six paintings instead of five. During test, participants saw six old items and four new. The assignment of the paintings to study or test phase was randomized across subjects. The artists' names were presented by their last name only (e.g., Pessani). The buttons in both the study and the test phases were changed from white to gray for saliency. There was also no repetition of the category items during study.

Results and Discussion

Overall, participants scored low on the questionnaire (M=8.31, SD= 4.41). Looking at performance during the study phase, as in Experiment 1, performance in the blocked condition (M = 0.58, SD = 0.19) was higher than in the interleaved condition (M = 0.33, SD = 0.12), t (40) = 7.07, p < .0001.

Of greater interest is performance during the test phase, depicted in Figure 3. As can be seen from the figure there was no difference in performance between the blocked and interleaved study conditions $F < 1$. There is also no difference in performance between categorizing new and old items, $F < 1$, nor an interaction between stimulus novelty and sequence, $F < 1$

The results from this experiment, although not definitive, suggest a role of item repetition during study in the test results of Experiment 1. That is, the main difference between Experiments 1 and 2 was the item repetition, and eliminating item repetition also eliminated the benefit for blocked over interleaved training. However, part of the advantage seen for blocked study in Experiment 1 might also come from the use of an active study procedure that includes repetition. One possibility is that in Experiment 2, active study strengthens the associative links between items and the correct category assignment that are created during study. These strong associations result in an advantage for blocked study, because it increases the likelihood that learners are able to identify the style and correctly select the artist name. These associative links provide an advantage during test, but not as large of an advantage as it would be when combined with the presence of item repetition (as in Experiment 1). We will come back to this hypothesis in the General Discussion.

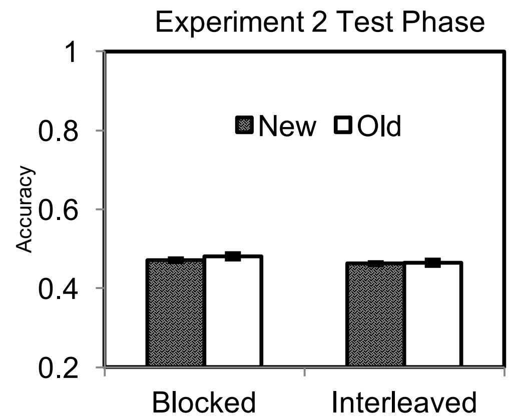

Figure 3. Performance during the test phase for the blocked and interleaved study conditions for new and old stimuli in Experiment 2. Chance performance in this task is 0.17. Error bars represent standard errors of the mean.

To ascertain that an interleaved study advantage could be found with our method, and that it is related to the use of a passive study situation in the absence of repetition, we conducted Experiment 3. In Experiment 3, learners study the paintings from different artists with the correct artist name displayed below them (passive study) and there is no item repetition during study.

Experiment 3

Method

Participants Forty-three undergraduate students at Indiana University volunteered to participate for partial course credit. Data from all participants was included in the final analyses.

Stimuli and Apparatus The stimuli were the same as in Experiments 1 and 2. The questionnaire was the same as in Experiment 2. Stimuli were presented and participants' responses were collected using E-Prime (Psychology Software Tools, Pittsburgh, PA) as in previous experiments.

Procedure The procedure is the same as in Experiment 2, except for the following changes. Instead of the participant having to choose from a list of six artists during study, the paintings are now shown with the correct artist name presented below it for three seconds. The procedure is passive so the participants were not required to click any buttons during study. There was no item repetition, similar to Experiment 2.

Results and Discussion

We started by analyzing the data from the questionnaire. The questionnaire was scored in the same way as the previous two experiments. Overall, participants scored low on the questionnaire (M=7.85, SD=4.40) and no participants reached the criterion of artist knowledge necessary to be removed.

Figure 4 shows the results of the test phase. Contrary to Experiments 1 and 2, interleaved study results in higher performance during the test phase compared to blocked study, $F\,(1{,}42) = 15.85$, $p < .001$, $\eta_G^2 = .11$.

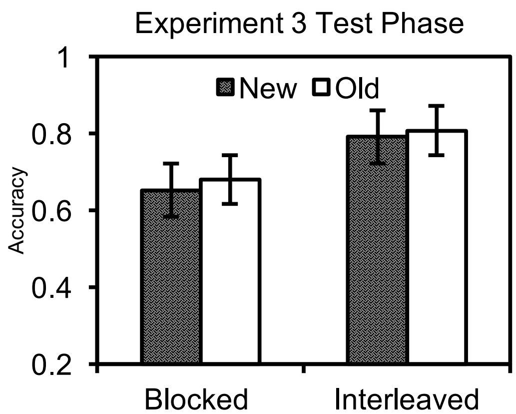

Figure 4: Performance during the test phase for the blocked and interleaved study conditions for new and old stimuli in Experiment 3. Chance performance in this task is 0.17. Error bars represent standard errors of the mean.

Moreover, similar to what we see in Experiment 1, performance is overall better for Old items compared to New items, $F\,(1{,}42) = 14.45$, $p < .0004$, $\eta_G^2 = .11$, and there is no interaction between the two variables, $F < 1$.

In sum, Experiment 3 replicates previous findings (Kang & Pashler, 2012; Kornell & Bjork, 2008; Kornell, 2010) showing that passive study with no repetition results in interleaved study having higher performance during test.

General Discussion

In this paper we looked at the influence of item repetition and study method (active vs. passive) on blocked and interleaved study across three experiments. We predicted that adding item repetition into an interleaved or blocked study might have differential effects on learning. More specifically, we predicted that adding item repetition into a blocked study would produce higher performance during test than interleaved study with item repetition.

We hypothesized that during blocked study, adding item repetition would result in better encoding of the category members due to the stronger associations between items of the same category created during the first presentation of the category. This, in turn, would result in learners recollecting the specific item when repeated but also the other temporally adjacent items from the same category during the second presentation (repetition) of each item. On the other hand, during interleaved study, adding item repetition would result in worse retrieval of other category members due to weaker associations between items of the same category created during the first presentation of the category. Items of the same category are presented farther apart in time during interleaved study, therefore the learner is less likely to identify communalities or create associations between items of the same category in the first place. The essence of this account is a putative reminding of same-category items occurring in the same temporal context.

Consistent with this prediction we found that in a situation in which there is item repetition, blocked study results in higher performance during test (Experiment 1). However, in a situation where there is no item repetition, there is no difference between blocked and interleaved study (Experiment 2).

A consideration of the role of temporally adjacent comparison provides an alternative explanation for the differential impact of item repetitions on interleaved and blocked training. Consistent with arguments about the cognitive importance of comparison for discovering critical commonalities between members of the same category (e.g., Gentner et al., 2003; Markman & Gentner, 2006), it is reasonable to posit that when two objects that belong in the same category are presented successively, their commonalities are highlighted. When an item is subsequently repeated, the commonalities that this item shares with other items from the same category will be selectively re-emphasized because they were originally how the blocked items were encoded. This account differs from the aforementioned "reminding of associated items" account because it posits that the within-category commonalities are selectively emphasized. In this view the entire category items, which possess features that are either idiosyncratic or common to the category are encoded and recalled. One result that is consistent with this "comparison-based commonalities" account is that repetition improves performance in the blocked study for both old and novel items to the same extent. If participants were being reminded of all the properties of items presented in the same context as a repeated item during study, then one might predict that these old, reminded items, would be particularly well categorized during test. However, the fact that we found equal benefits for old and new items at test is consistent with the blocked advantage stemming from encoding of the features that these two types of items share – namely, the characteristic features shared by all category members.

Adding item repetition also results in the inclusion of temporal spacing between item repetitions unlike interleaved and blocked study in which the only spacing is between category repetitions (Kornell & Bjork, 2008; Birnbaum et al., 2014; Kornell, 2009; Kornell et al., 2010; Kang & Pashler, 2012). In fact, increased temporal spacing between item repetitions has been shown to result in better memory than temporal spacing between similar items (akin to category repetitions; Thios, 1972). However, temporal spacing between item repetitions does not differ between the interleaved and blocked study in Experiment 1 and therefore this factor cannot explain our current results.

The results presented here also reiterate the role of the study modality as a modulator of the relative advantage of interleaved or blocked study (Carvalho & Goldstone, 2015). Here we found that a blocked study advantage (Experiment 1) or equal performance between the two study sequences (Experiment 2) is associated with active study situations while interleaved study is more beneficial in a passive study situation. The current studies use categories where there is no simple description of a categorization rule (information-integration categories, Ashby & Maddox, 2005) and participants simultaneously learn a large number of categories. These two factors might have critically contributed to the benefits of interleaved sequences for passive study and blocked sequences for active study. It is possible that an active study situation promotes greater association between the items and the label being presented, which might be a particular difficulty when studying six categories. Passive study, on the other hand, might promote rule-based categorizations, even when information-integration categories are used, similarly to what is seen with unsupervised study (Ashby et al., 1999). The larger opportunity to compare items from different categories afforded by interleaved study would make finding a partial categorization rule more likely. Moreover, the sequence manipulation might result in different levels of passive study. Because it is easy to predict the next category, blocked active is more passive than interleaved active. The same is true for the passive study conditions. This might further influence the attentional patterns established during study and contribute to the results seen here.

An important next step would be to look at the effects of item repetition in a passive study condition to fully understand how the type of study influences the creation of item-item associations and its use during item repetition. It would also be important to directly test the strength of inter-item associations within and between the interleaved and blocked schedules.

In educational settings, students and teachers alike implement various strategies to try to facilitate learning. One major kind of general and strategic flexibility that individuals have in trying to maximize learning efficiency is in determining how to sequence examples of different categories. This research has shown that the common strategy of reviewing the same materials a second time after an initial pass might render blocked study more beneficial than interleaved study.

Acknowledgments

This research was supported in part by National Science Foundation REESE grant 0910218 and Department of Education IES grant R305A1100060 to RLG, and Graduate Fellowship SFRH /BD/78083/2011 from the Portuguese Foundation for Science and Technology (FCT) to PFC. Stimuli images courtesy of Nate Kornell (http://sites.williams.edu/nk2/stimuli/)

References

Ashby, F. G., & Maddox, W. T. (2005). Human category learning. *Annual Review of Psychology*, *56*, 149–78.

Ashby, F. G., Queller, S., & Berretty, P. M. (1999). On the dominance of unidimensional rules in unsupervised categorization. *Perception & Psychophysics, 61*(6), 1178–99.

Birnbaum, M. S., Kornell, N., Bjork, E. L., & Bjork, R. A. (2013). Why interleaving enhances inductive learning: The roles of discrimination and retrieval. *Memory & Cognition, 41*(3), 392-402.

Carvalho, P. F., and Goldstone, R. L. (2014). Putting category learning in order: category structure and temporal arrangement affect the benefit of interleaved over blocked study. Memory & Cognition. 42(3), 481–495.

Carvalho, P. F., and Goldstone, R. L. (2015). The benefits of interleaved and blocked study: different tasks benefit from different schedules of study. *Psychonomic Bulletin & Review, 22*, 281-288.

Gentner, D., Loewenstein, J., & Thompson, L. (2003). Learning and transfer: A general role for analogical encoding. *Journal of Educational Psychology, 95*(2), 393.

Hintzman, D. L. (2010). How does repetition affect memory? Evidence from judgments of recency. *Memory & Cognition, 38*(1), 102–15.

Kang, S. H. K., & Pashler, H. (2012). Learning Painting Styles: Spacing is Advantageous when it Promotes Discriminative Contrast. *Applied Cognitive Psychology, 26*, 97–103.

Kornell, N., & Bjork, R. A. (2008). Learning concepts and categories: Is spacing the "enemy of induction"? *Psychological Science*, *19*(6), 585–592.

Kornell, N. (2009), Optimising learning using flashcards: Spacing is more effective than cramming. *Applied Cognitive Psychology*, 23, 1297–1317.

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 Aging, 25*(2), 498–503.

Mitchell, C. & Hall, G. (2014). Can theories of animal discrimination explain perceptual learning in humans? *Psychological Bulletin, 140*(1), 283-307.

Ross, B. H., Perkins, S. J., & Tenpenny, P. L. (1990). Reminding-based category learning. *Cognitive Psychology, 22*(4), 460–492.

Ross, B. H. (1984). Remindings and their effects in learning a cognitive skill. *Cognitive Psychology, 16*(3), 371–416.

Taylor, K., & Rohrer, D. (2010). The effects of interleaved practice. *Applied Cognitive Psychology*, *24*(6), 837–848.

Thios, S., (1972). Memory for Words in Repeated Sentences. *Journal of Verbal Learning and Verbal Behavior, 11*, 789-793.

Wahlheim, C. N., Dunlosky, J., & Jacoby, L. L. (2011). Spacing enhances the learning of natural concepts: An investigation of mechanisms, metacognition, and aging. *Memory & Cognition, 39*(5), 750–763

Markman, A. B., & Gentner, D. (1996). Commonalities and differences in similarity comparisons. Memory & Cognition, 24(2), 235-249