COMBINING BLOCKED AND INTERLEAVED PRESENTATION DURING PASSIVE STUDY AND ITS EFFECT ON INDUCTIVE LEARNING

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COMBINING BLOCKED AND INTERLEAVED PRESENTATION DURING PASSIVE STUDY AND ITS EFFECT ON INDUCTIVE LEARNING

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ABSTRACT

COMBINING BLOCKED AND INTERLEAVED PRESENTATION DURING PASSIVE STUDY AND ITS EFFECT ON INDUCTIVE LEARNING

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Past research has shown that interleaved presentation produces better recall when compared to blocked presentation. However, the structure of the study session can alter the effectiveness of interleaved over blocked study. Kost, Carvalho, and Goldstone (2015) found that repeating study items resulted in a benefit of blocked over interleaved presentation when items were studied actively. However, the effect of repetition during passive study, as well as the combination of both blocked and interleaved presentation during repeated study, remains unknown.

The present experiment replicated the method of Kost and colleagues’ (2015) to evaluate a combined method which involves the presentation of study items in blocks followed by the repeated presentation of the same study items in interleaved order. The experiment also aimed to extend the findings of Kost and colleagues by evaluating the effectiveness of interleaved versus blocked presentation when participants study items passively. Combined presentation and interleaved-only presentation resulted in higher test performance than blocked-only presentation, but there was no significant difference between interleaved presentation and combined presentation.
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INTRODUCTION

Inductive learning is a process by which individuals learn new concepts and categories by observing examples (Kornell & Bjork, 2008). To successfully categorize items, the learner must attend to the features that define each category, rather than simply memorize each example by viewing it as a whole (Carvalho & Goldstone, 2013). For example, when learning a set of paintings that have been categorized by artist, the learner must view examples of paintings by each artist to identify the techniques and stylistic qualities that are unique to a particular artist’s works. The learner’s knowledge of these unique features will help him/her distinguish between artists, as well as group paintings together that were created by the same artist (Rohrer, 2012).

The order in which the individual learns categories has been shown to affect later accuracy of categorization of both novel and previously learned stimuli (Kornell & Bjork, 2008). Two specific methods have commonly been used to explore the effect of item presentation on recall: blocked and interleaved presentation. Blocking involves the grouping of items from the same category together, whereas interleaving involves the presentation of an item from one category followed by an item from another category (Birnbaum, Kornell, Bjork, & Bjork, 2013). For example, if the learner is observing a collection of paintings by three different artists (Georges Braque, Phillip Juras, and Bruno Pessani) in blocked presentation, he/she would view all of the paintings created by
Braque, followed by all of the paintings by Juras, followed by all of the paintings by Pessani. If the learner is observing this set of paintings in interleaved order, he/she would view a single Braque painting, followed by a Juras painting, following by a Pessani painting. The learner would then view the next Braque painting and repeat the viewing pattern until all paintings by all artists have been shown.

A growing body of research investigates how inductive learning can be improved by employing different orders of category presentation during study. Interleaving and blocking vary in how each method directs the learner’s attention toward the features of each example, thus affecting what is learned about the category. Interleaved presentation emphasizes features that differentiate categories, whereas blocked presentation tends to emphasize features that are shared among the items belonging to the same category (Carvalho & Goldstone, 2013). Researchers have generally found that inductive learning is more greatly enhanced when examples of different categories are interleaved to allow learners to grasp the differences between the categories being studied (Kornell & Bjork, 2008). This is known as the discriminative-contrast hypothesis (Birnbaum et al., 2013). Another name for the discriminative-contrast hypothesis is the “search-for-differences” hypothesis. This hypothesis states that when individuals attempt to identify unique attributes of a particular category, they develop their concept or categorization rule for that category by contrasting examples of that category with examples of other categories (Goldstone, 1996; Tauber, Dunlosky, Rawson, Wahlheim, & Jacoby, 2013).

In contrast, the “search-for-similarities” hypothesis states that individuals develop their categorization rules by identifying how examples of a single category are similar. Rather than attending to the contrasts between paintings of various artists, learners attend
to the similarities among all paintings by a single artist that best define the artistic style that is attributed to that artist. (Tauber et al., 2013). These hypotheses present two different strategies that learners may use when categorizing items. While the contrast-focused strategy of “search-for-differences” is most compatible with interleaved presentation, the “search-for-similarities” strategy is most compatible with blocked presentation. This is because blocked presentation allows for successive views of exemplars from a single category, thus increasing the salience of features shared by a category’s members.

The advantage of interleaving over blocking, and vice-versa, seems to depend on a number of factors, including the type of material being learned. Frequent alternation between categories, as seen with interleaving, is particularly helpful when differences between categories are difficult to identify (Zulkiply & Burt, 2013). For example, if the learner is viewing a set of paintings by various artists yet all the paintings are landscapes, interleaving allows the learner to determine which features are important for distinguishing one artist from another. Since the subject matter for all paintings is the same, interleaving promotes the formation of categorization rules for each category, which would be particularly difficult if the learner were to view all paintings in blocks by artist.

For example, if learners were viewing landscapes by Bruno Pessani in blocked order, they would likely first identify that the distinguishing feature shared among all of Pessani’s paintings is the subject matter. However, if, after viewing the Pessani paintings, learners then viewed landscapes by Ryan Lewis, they would realize that this categorization rule no longer applies. They would then have to identify a new feature that
distinguishes Pessani’s works from Lewis’ works. In contrast, if learners viewed Pessani’s paintings interleaved with Lewis’ paintings, they would more quickly realize that landscapes are not a distinguishing feature of either artist’s paintings and that other features would need to be identified to differentiate the artists. This understanding would be acquired more quickly as learners would only need to view a few of each artist’s paintings before identifying the distinguishing features, as opposed to viewing all of the paintings by one artist then realizing their categorization rule was incorrect when the second artist is shown.

Alternatively, blocked presentation encourages the learner to notice the commonalities among items within the same category which is beneficial if all members within a single category are very different from one another (Carvalho & Goldstone, 2014). For example, if the learner is viewing sets of landscapes, portraits, and still-life paintings all by a single artist, blocked presentation allows the learner to group together the common stylistic qualities among all the various contexts and associate them with their respective artist. This leads to better categorization of novel members, because the learner is able to encode the relevant features shared among the paintings and their single category label more effectively. In contrast, a number of studies, such as Kornell & Bjork’s (2008) study using paintings and Birnbaum et al. (2013)’s study using bird species, feature a series of stimuli that exhibit high similarity between categories. Therefore, in these studies, interleaving was shown to be advantageous as a result of the type of natural categories being presented.

The learner’s level of engagement during the study period, where categorization rules are first established, can also influence the effectiveness of interleaving and
blocking on inductive learning. Carvalho and Goldstone (2013) evaluated two approaches to inductive learning, active and passive study, and their relationship with interleaved and blocked study. Active study requires learners to assign a category label to a never-before-seen stimulus and update their categorization rules using subsequent feedback. For example, if learners were viewing a Braque painting, they would view the painting without the name “Georges Braque” presented simultaneously. They would then choose from a list of possible painters. Of course, if the learners had never seen this painting before, they would likely make the wrong categorization. Corrective feedback allows them to form and update their categorization rules to match the painting’s style and its respective painter. Interleaved presentation was most effective with active study, for it allowed learners to focus on the differences between categories when assigning labels. Passive study, however, does not encourage learners to focus on qualities that allow them to discriminate between categories. For example, if the learner viewed a never-before-seen Braque painting, he/she would simply be simultaneously provided with the label “Georges Braque.” This pairing causes learners to focus on the association between the category member and its label, “Georges Braque.” Passive study thus encourages the learner to identify the similarities amongst all the Braque paintings, because it does not use corrective feedback to encourage learners to consider other categories. Blocked presentation is therefore most effective with passive study, for it also encourages learners to focus on the similarities among features within a single category. While Carvalho and Goldstone (2013) found that this compatibility led to better recall and categorization of novel members, a follow-up study by Kost et al. (2015) found that presenting a second study period produced different effects on inductive learning, thus altering the
compatibility between blocked presentation and passive study, and interleaved presentation and active study.

Kost et al. (2015) initially aimed to determine whether the associations established between categories during the first study period differed between interleaved and blocked study. If they did, then Kost et al. inferred that it would be likely that a second study period would have a different effect depending on whether learning was active or passive. They hypothesized that, when categories are presented in blocks, the common features among examples within the same category that are encoded during the first presentation of items during the study period are selectively and more quickly reactivated when items are repeated. For example, if learners first viewed Braque’s paintings in a block, they would be more likely to identify the features that were common across all of Braque’s paintings. After viewing all other paintings and determining which categorization rules are most important for distinguishing Braque’s paintings from the others, the second blocked presentation would allow learners to quickly reactivate the features they had previously encoded as all of Braque’s paintings would be presented successively again. Alternatively, when categories are interleaved, individuals are less likely to identify commonalities among examples of the same category during the first presentation of items. This results in less reactivation of common features when items are repeated. Using this method, all paintings by Braque would be interleaved between paintings by other artists. Therefore, it would take longer to view all of Braque’s paintings than it would if his paintings were presented as a block. Considering this, it would be more difficult to identify the common features shared by all Braque paintings, resulting in fewer commonalities encoded. Therefore, when all of the paintings are
repeated, these commonalities would be less likely to be reactivated due to the learner’s focus on discriminatory qualities between categories during interleaved presentation. While Carvalho and Goldstone (2013) found that interleaving produces greater categorization learning during active study, Kost et al. observed that blocked presentation was superior to interleaved presentation when items were repeated during active study.

This could, in part, be a result of a change in the constraints of active study. The paradigm of Kost et al. (2015), which is partially replicated in the present study, requires participants to learn six categories of paintings that are all very similar. The number of categories, and the type of categories used, might make learning a categorization rule difficult with interleaved presentation and active study. Active study strengthens the associative link between a category member and its label (Carvalho & Goldstone, 2015). These associations could create an advantage for blocked presentation by producing stronger encoding of category members during the first presentation of each category. For example, imagine that learners are actively studying Braque paintings in blocks. As previously stated, blocked presentation would orient learners toward focusing on the commonalities among all the Braque paintings. In addition, with active study, learners would also have to choose each painting’s category label “Braque” among all possible options. During this process, learners would be likely to initially choose incorrectly and be provided corrective feedback; however, after a few Braque paintings are shown, the learner would note the similarities between the painting they are viewing and the Braque paintings they just saw. This recognition of shared qualities would strengthen the associative link between the paintings and the label “Braque” during this first study.
period, as they would be more likely to choose the correct label as more Braque paintings are shown successively.

Meanwhile, according to Kost et al. (2015), repeating items following an initial interleaved study period might result in worse retrieval due to weaker associations between category and label during the initial presentation. If learners are actively studying interleaved Braque paintings, the spaced nature of interleaving would make it more difficult for learners to recall what previous Braque paintings looked like. Therefore, during active study, it would likely take more trials of Braque paintings for the learner to consistently identify that a painting is a Braque painting than it would if the paintings were blocked. This would mean that the associative link between the paintings and the label “Braque” would not be a quickly encoded and strengthened during the initial study period. Thus, a second study period may not be beneficial for rehearsing the categorization rules developed, because the learner did not initially encode a strong association between each artist and their respective paintings.

This advantage of blocked presentation may be exclusive only to active study paradigms with item repetition, however. Kost et al. (2015) observed in a follow-up study that interleaved presentation, not blocked, was more beneficial during passive study with only one presentation of study items. In this follow-up study, Kost et al. concluded that passive study promoted rule-based categorization even when categories are difficult to discriminate, similarly to rule generation during unsupervised learning (Ashby, Queller, & Berretty, 1999). However, Kost et al. did not investigate the potential benefit of interleaved presentation during passive study when items are repeated. Kost et al. hypothesized that a second viewing opportunity would provide the learner with more
opportunities to compare items of different categories if items are interleaved. The learner would therefore be more likely to develop at least a partial categorization rule. For example, if the learner saw a previously-viewed Braque painting, Juras painting, and Pessani painting, the second view would allow the learner to strengthen their previous encoding of these categories by allowing them another opportunity to compare and differentiate the styles of each artist. This second opportunity might allow the learner to develop at least a partial categorization rule, or the identification of a single defining feature, such a choice of color or brush stroke, unique to a single artist which could help differentiate between the artists. If the learner can determine a full categorization rule, they would be able to determine a painting’s category membership by a number of unique features that are uniformly different compared to each of the other artists. By affording the learner more time to make comparisons between categories, the learner’s development of categorization rules may provide greater recall when compared to blocked presentation. This is contrary to active study, which strengthens the association between category example and label, thus rendering interleaving ineffective since a partial categorization rule cannot be formed. The potential effectiveness of interleaving when repeated passive study is performed will be described later as a hypothesis for the present study.

Using the repeated-study paradigm introduced by Kost et al. (2015), the present study explored the effects of combining blocked and interleaved study. As previously discussed, the optimal method of study depends on the materials being studied as well as the learner’s engagement during study; however, no published study to date has investigated the combined effect of blocked and interleaved presentation on inductive
learning. Considering that, in practical application, learning strategies are often combined and repeated during study, it is important for researchers to observe how different learning strategies may be combined into a single study regimen. Past studies have indicated that learners may study blocked materials more passively than interleaved, thus reducing the amount of attention given to category items as the learner anticipates which label will be assigned to the next item (Rohrer, 2012). Thus, a transition from blocked to interleaved presentation could maintain the learner’s attention by emphasizing the learner’s need to focus on different features of each example when items are repeated. By doing so, the learner might experience a greater difficulty based on the increase of attentional demands (Richland, Bjork, Finley, & Linn, 2005). For example, if learners were to view paintings in blocked order once, then again in blocked order, they would anticipate, after seeing the first painting, that the paintings to follow would also be from the same artist. Thus, less attention would be given to each category during second study which would decrease the amount of rehearsal during item repetition. However, if items are presented again but in interleaved order, the learner would be more likely to attend to each painting due to the novelty of the presentation order. Having developed strong associative links between each painting and its respective artist during initial blocked study, a second study period would encourage learners to attend to, and discriminate between, the interleaved paintings.

While Kost et al. (2015) found a benefit of blocked presentation that allows learners to form strong associations among items of the same category, it is important that learners are also able to discriminate between categories (Zulkiply & Burt, 2013). Therefore, introducing interleaved presentation following blocked presentation could
provide the learner an opportunity to learn the distinguishing features of each category. Considering this emphasis on between-category discrimination as afforded by interleaving, it is likely that combining interleaved and blocked presentation will produce greater learning than either method alone. Elio and Anderson (1984), who studied the role of information order on category learning, suggested that learning should begin with low variability between exemplars and introduce greater variability between exemplars as learning progresses. Such variability could be achieved by employing this combined method of study. Presenting items in blocks would introduce a learning environment with low variability between exemplars initially, as all members of one category are shown before another category is introduced. The variability between exemplars would then increase during the second study period wherein items are interleaved. For example, the learner would first view all of the paintings by Braque, followed by all paintings by Juras, followed by all paintings by Pessani. This would be a display of low variability, because the learner would see consecutive paintings by one artist before viewing the paintings of another artist. If the learner were to then view the same items again with interleaved presentation, he/she would view the items with greater variability by viewing a Braque painting, then a Juras painting, then a Pessani painting. This increase in variability would also increase the learner’s ability to differentiate between categories, as he/she would have already encoded the similarities amongst category members by viewing them in blocks first. This combined approach should benefit learning by allowing the learner to first make strong within-category associations, which should in turn strengthen later between-category discriminations.
The present study utilized the repeated study paradigm introduced by Kost et al. (2015) to test two key hypotheses. First, while Kost et al. found that interleaved presentation was more effective compared to blocked presentation with passive study, they did not investigate the role of repetition of study items on inductive learning. The present study therefore aims to determine if learning differs when learners view items presented in blocked or interleaved presentation during passive study with item repetition. The present study will test the hypothesis that individuals who view interleaved presentation for both halves of the study period will outperform those who view blocked presentation when passive study is performed. This advantage of interleaved presentation is hypothesized to be present when analyzing only previously viewed stimuli, only novel stimuli, and when overall learning is assessed by combining accuracy of novel and previously learned stimuli during analysis. Passive study allows the learner to form rule-based categorization when between-category discrimination is difficult, as is the case with the paintings used in the proposed study. Passive study is therefore most compatible with interleaved presentation, which was hypothesized to have produced the advantage observed by Kost et al. despite an absence of item repetition. When items are interleaved and repeated, it is hypothesized that learners viewing the repeated items will be provided a second opportunity to compare items from different categories and strengthen the rules for categorization that were formed during the initial study. Meanwhile, individuals who learn categories through blocked presentation will suffer with passive study. Blocked study is already more naturally passive than interleaved study (Kost et al., 2015). Therefore, a second presentation of items using blocked presentation will further reduce the attentional demands of the learner. This may
reduce performance in later testing, for the learner will have failed to strengthen their categorization rules during repeated study.

The second hypothesis states that those who study using combined presentation, comprised of blocked presentation then interleaved presentation when items are repeated, will outperform those who study using only interleaved presentation when tested. This advantage of combined presentation is hypothesized to be present when analyzing only previously viewed stimuli, only novel stimuli, and when overall learning is assessed by combining accuracy of novel and previously learned stimuli during analysis. Presenting category members by block first may allow learners to make strong associations between each example and its category label (Carvalho & Goldstone, 2014). By encoding this association first, the learner may form a strong foundation on which he/she can determine a categorization rule when items are repeated and interleaved. For example, if the learner is introduced first to all of the paintings by Braque in a block followed by a block of Juras and a block of Pessani, he/she might identify the commonalities shared by members within a block. When the same Braque paintings are repeated in interleaved presentation, thus juxtaposed with paintings by Juras and Pessani, the learner may have a strong reference point from which he/she can determine how Braque’s style differs from Juras’ and Pessani’s style. This is hypothesized to allow the learner to more accurately categorize novel and previously viewed examples of each category when later tested when compared to learners who view items in only interleaved presentation.
METHOD

Participants

The participants in this study were 122 undergraduate students at the University of Dayton who were recruited through Sona Systems. Data were analyzed for 120 participants, as 2 participants were excluded from this study for exceeding the maximum score on the portion of the questionnaire assessing familiarity of famous artists. Regardless of one’s inclusion in the data, each student received one hour of research credit for their participation in the study.

Materials

Stimuli. The stimuli consisted of 60 paintings by 6 artists with 10 paintings created by each artist (see Appendix). These stimuli have been used in past studies, including those conducted by Kornell and Bjork (2008) and Kost et al. (2015). The artists were Georges Braque, Henri-Edmond Cross, Judy Hawkins, Philip Juras, Ryan Lewis, and Bruno Pessani. All paintings featured either landscapes or skyscapes. Superlab 5.0 sequentially displayed the stimuli on an iMac desktop computer. The paintings were kept in their original sizes, as obtained from Kost et al. (2015), to maintain their intended proportions. Landscape oriented paintings ranged from 334x274 pixels to 540x357 pixels. Portrait oriented painting ranged from 257x360 pixels to 333x447 pixels. No
paintings featured any names or signatures which might have allowed the painting/painter to be identified.

**Questionnaire.** A questionnaire was administered to assess previous artistic knowledge, similar to that which was provided by Kost et al. (2015). The questionnaire consisted of a list of the names of 18 artists in three categories: famous artists, artists featured in the experiment, and fake artists. Each participant was asked to circle the names of the artists with whom he/she was familiar. Their familiarity with each artist could be derived from having heard an artist’s name before, or from remembering the artist’s works. This questionnaire was administered via pencil and paper and scored in the following way: For each artist included in the experiment who was correctly recognized (by circling the target name), 2 points were added to the participant’s total score. For every fake artist selected, 1 point was deducted, and for each famous artist that was recognized, 1 point was added to the total score. If a participant earned a score of 10 or higher out of the maximum 18 points, he/she was excluded from the analysis. The questionnaire also required participants to list their major and minor, and the number of fine arts courses that they had taken.

**Procedure**

Participants began by completing the prior knowledge questionnaire. Following its completion, participants began the study period of the experiment. There were three sections of the experiment in total: a study period, a distractor task, and a test. During the study period, 36 paintings (6 from each artist) appeared sequentially on the screen for 3 seconds each with the corresponding artist’s last name appearing below the painting. For
each trial, the learner was instructed to simply study the painting and its category label and was not required to press any buttons or provide any responses during study (See Appendix B for the set of instructions verbally provided to the participant). Once all 36 paintings were viewed, the presentation of paintings was repeated and the learner studied the same 36 items again. The order of stimuli presentation during the study period differed in accordance with the experimental condition: blocked presentation, interleaved presentation, and combined presentation. In the combined condition, participants viewed paintings in blocked order during the first study period. During the second study period, participants viewed paintings in interleaved order. In the blocked condition, participants viewed blocked presentation for both study periods. Likewise, in the interleaved condition participants viewed interleaved presentation for both study periods. During blocked study periods, participants viewed each of the six paintings of one artist before studying the next artist. During interleaved study periods, participants viewed one painting by each of the six artists. Once these paintings were studied, participants viewed the next example painting by each of the six artists. This order continued until all paintings had been shown for that study period. The sequence of paintings during the study period was fixed for all participants within each condition. Furthermore, this fixed sequence was repeated for both presentations during the study period in the blocked and interleaved conditions. Paintings were also fixed in the combined condition such that painting orders for the blocked period and the interleaved periods of study were the same across all participants in this condition.

Following the study period, a distractor task was administered in the form of a counting backwards task. To begin this task, participants were first provided with four
single-digit numbers to remember. Immediately upon receiving these numbers, participants were asked to count backwards aloud by threes from a three-digit number. Participants counted backwards for a total of three minutes. Once three minutes had elapsed, participants were asked to recall the original four digits provided at the start of the task. This distractor task deviated from Kost et al.‘s original trivia distractor task. This task was designed to increase the amount of cognitive load required during the distractor task while maintaining the 3-minute duration occupied by the original trivia task.

Following the distractor task, the test occurred. Participants viewed the 6 paintings by each artist that were previously studied, as well as 4 new paintings by each artist that were not provided during the study period, for a total of 60 test items. Each painting appeared sequentially on the screen with the last names of all artists appearing below it. Participants were then asked to click on the name of the artist they believed created the painting. Unlike the study period, the order in which the paintings were presented was randomized during the test period for each participant regardless of condition. The test was forced choice such that participants were not given an option to skip a painting, nor were they given the option to answer “I Don’t Know” when choosing an artist’s name. Participants, however, were given as much time as needed to identify each painting’s artist. The order in which the artists’ names were listed as possible answers below each test painting was initially randomized. This was performed to avoid having artists’ names appear in the same sequence as they were presented during study. Once randomized, the new order of names was fixed across participants, such that all participants saw each possible answer in the same position on the screen.
RESULTS

Table 1 indicates the mean proportion recalled during the test period for each condition, and for overall performance collapsing across conditions. Separate means are reported for proportion recall of previously viewed items, novel items, and total items. See Figure 1 for mean differences in average categorization as a function of presentation order and painting type. A one-way analysis of variance indicated that overall test performance varied as a function of study presentation method, $F(2, 117)=6.297$, $MSE=0.092$, $p=.003$, $\eta^2=.097$. Two comparisons were conducted. The average proportion of total paintings correctly categorized by the interleaved group ($M=0.93$, $SD=0.11$) was higher than the blocked group ($M=0.85$, $SD=0.14$), $t(117)=-2.968$, $p=.004$, $r^2=.092$. However, the proportions of total paintings categorized did not significantly differ between the combined group ($M=0.94$, $SD=0.11$) and the interleaved group, $t(117)=-0.201$, $p=.841$. One additional post-hoc comparison was also conducted. The combined group categorized more paintings correctly compared to the blocked condition, $t(117)=-3.169$, $p=.002$, $r^2=.113$.

A second one-way analysis of variance indicated that recall of previously viewed paintings varied as a function of study presentation method, $F(2, 117)=5.934$, $MSE=0.092$, $p=.003$, $\eta^2=.097$. Two additional comparisons were conducted. The average proportion of total paintings correctly categorized by the interleaved group ($M=0.93$, $SD=0.11$) was higher than the blocked group ($M=0.85$, $SD=0.14$), $t(117)=-2.968$, $p=.004$, $r^2=.092$. However, the proportions of total paintings categorized did not significantly differ between the combined group ($M=0.94$, $SD=0.11$) and the interleaved group, $t(117)=-0.201$, $p=.841$. One additional post-hoc comparison was also conducted. The combined group categorized more paintings correctly compared to the blocked condition, $t(117)=-3.169$, $p=.002$, $r^2=.113$. 
MSE=0.072, p=.004, \( \eta^2 = .092 \). Two comparisons were conducted. The average proportion of previously viewed paintings recalled by interleaved group (\( M=0.95, SD=0.10 \)) was higher than the blocked group (\( M=0.87, SD=0.13 \)), \( t(117)=-3.077, p=.003, r^2=.106 \).

However, the average proportion recall of previously viewed paintings did not significantly differ between the combined group (\( M=0.94, SD=0.10 \)) and the interleaved group, \( t(117)=-0.198, p=.844 \). One post-hoc comparison was also conducted. The combined group recalled more previously viewed paintings compared to the blocked condition, \( t(117)=-2.880, p=.005, r^2=.083 \).

Finally, a one-way analysis of variance indicated that categorization of novel paintings varied as a function of study presentation method, \( F(2, 117)=6.229, MSE=0.129, p=.003, \eta^2=.096 \). Two comparisons were conducted. The interleaved group (\( M=0.92, SD=0.14 \)) significantly categorized more novel paintings when compared to the blocked group (\( M=0.83, SD=0.17 \)), \( t(117)=-2.682, p=.008, r^2=.077 \). The average proportion of novel paintings correctly categorized did not differ between the combined group (\( M=0.93, SD=0.12 \)) and the interleaved group, \( t(117)=-0.646, p=.519 \). One post-hoc comparison was also conducted. The combined group correctly categorized more novel paintings compared to the blocked condition, \( t(117)=-3.328, p=.001, r^2=.103 \). Across the conditions, previous artist knowledge was very low (\( M=3.33, SD=2.05 \)).
DISCUSSION

As predicted, the benefit of interleaved over blocked order was observed following repeated study. This is both in agreement with the first hypothesis, and is consistent with Kost et al.’s (2015) finding that interleaved study was beneficial when single-presentation passive study was performed. Considering that it is common for learners to study items in blocked order and believe that this order is most beneficial for learning, these results are critical for adding to the body of support for alternative study presentation methods (Birnbaum et al., 2013). Kost et al.’s (2015) series of experiments were the first to observe the effect of presentation order on inductive learning using a repeated study paradigm. Considering that most materials to be learned are studied multiple times before testing occurs, it is important for researchers to continue to evaluate the effectiveness of blocked and interleaved study across repeated study. The results in this study suggest that blocked presentation is not effective during passive practice with repeated study.

The results detailed here also provide partial evidence for the benefit of combined study during repeated passive practice. Participants who studied using the combined method significantly outperformed those who studied using the blocked-only method; however, there was no difference in performance between those who studied using the combined method and those who studied using the interleaved-only method. This pattern
of results is the same when test performance was broken down into previously viewed painting categorization and novel painting categorization only. In sum, while combined study was shown to indeed produce better learning of categorization rules compared to blocked study alone, there was no benefit of combined study over interleaved-only study. The results also indicated that interleaved-only study produced better learning of categorization rules compared to blocked-only study, which provides support for the first hypothesis tested in this experiment.

The present experiment aimed to fulfill two key objectives. The first objective of this experiment was to extend the research of Kost et al. (2015) to determine differences in learning following interleaved-only or blocked-only study during repeated passive practice. While Kost et al. tested a number of repeated and single-study paradigms using either passive or active practice, they did not investigate repeated passive practice. Despite this, Kost et al. suggested a key hypothesis that was directly tested in the present experiment: Interleaved presentation is most beneficial during repeated passive study when compared to blocked presentation. This was assumed to potentially occur because of the attentional demands imposed by repeated passive study. The authors stated that the ability to predict the next category to be presented creates an environment in which blocked study is more passive than interleaved study. The lower attentional demand derived from repeated blocked study could have detrimental effects on learning, for learners may not work to continue forming and strengthening their categorization rules when viewing paintings the second time. This hypothesized lack of attentional demand over time could be a result of the difficulty of the task (Birnbaum et al., 2013). When items are repeated during blocked study, the predictability of item presentation would
reduce attention to features of each painting that distinguish it from paintings by other artists. This predictability would make studying items easier to learners, since their ability to predict the category to which the next painting belongs could cause the learner to believe that they know the rules for categorizing that artist without needing to focus on studying each painting again. If learners are not attending to the unique features of each painting as closely as they would if the items are interleaved, then they will likely not form the categorization rules necessary to categorize previous paintings, nor be able to extend those rules to novel paintings by the same artists. The present experiment therefore aimed to directly test this paradigm with the assumption that interleaved presentation would provide the attentional demands necessary to enhance learning of categorization rules, and thus produce better categorization of both previously viewed and novel paintings when compared to blocked-only study.

The second objective of this study involved the development of a combined presentation order comprised of blocked then interleaved presentation of repeated study items. This repeated study order was developed as an alternative approach to blocked-only and interleaved-only presentation. This combined presentation method was implemented under the assumption that specifically viewing items in blocked order first, then interleaved order, would be advantageous in allowing learners to establish strong associative links between category labels (artists’ names) and category members (paintings). When compared to interleaved-only presentation, the combined presentation method was predicted to produce higher proportions of correct categorization of paintings in the overall test. In addition, performance was broken down to testing of previously viewed paintings and novel paintings to determine if combined presentation not only
improved recall of the studied paintings and their artists, but also improved transfer of the categorization rules developed during study to novel paintings by the same artists.

It was hypothesized that the benefit of combined study was derived from the strengthening of categorization rules during interleaved study when items are repeated following initial blocked study. It was predicted that first providing learners an opportunity to form strong initial within-category associations would create a foundation on which learners would be able to form more complete categorization rules when later making between-category discrimination during repeated, interleaved presentation. This was hypothesized to be more beneficial to learning than interleaved-only presentation, for it was predicted that initial interleaved study would be too difficult to facilitate strong within-category associations. These associations are necessary for later formation of between-category discriminations when study is repeated.

As Elio and Anderson (1984) stated, recall is improved when examples of categories are presented with low variability first then increased in variability as learning progresses. Furthermore, they found that the successful transfer of categorization rules to novel members increased when variability was progressively increased during study. Elio and Anderson argued that presenting more items from the same category first, then gradually introducing more categories then switching between those categories frequently, facilitated the development of categorization rules. As opposed to interleaved-only study, which initially features high variability between examples, combined study is designed specifically for learners to familiarize themselves with each category through blocked presentation before increasing the variability by interleaving members of different categories.
It is possible that gradually increasing the variability between categories creates a more desirable level of difficulty for the learner. A desirable difficulty, according to Bjork and Bjork (2011), is level of difficulty which triggers encoding and retrieval to support learning and remembering. If the level of difficulty in a task is too low, the learner will not continue to attend to the task and thus will not reactivate the encoded material as it progresses. If the level of difficulty is too high, the encoding of information will be inhibited because the learner will not have the skills or knowledge necessary to correctly identify the information to be remembered. It was therefore hypothesized that combined study would provide learners with a more desirable level of difficulty compared to interleaved study, which might make the development of categorization rules too difficult during the initial study to produce any additional benefits when paintings are repeated during study.

This hypothesis was not confirmed by the results presented here, considering that there was virtually no difference in performance between those who studied using the combined method and those who used the interleaved-only method. However, it is important to note here that there was a ceiling effect in the data, such that the overall mean for total proportion recall for the combined condition and interleaved condition were 0.943 and 0.937 respectively (See Table 1). This indicates that the average score on the test for both conditions was around 94%. It is important to note here that an arcsine transformation was performed with the aim of adjusting for the negatively skewed distribution of the data; however, despite this transformation, the ceiling effect remained. While no difference was observed between performance following interleaved and combined study, this ceiling effect may have rendered any differences between
interleaved and combined study undetectable. However, interleaved and combined presentation, both which involved interleaving in the second study period, produced greater learning than blocked presentation. Thus, it is important here to consider the effect that task difficulty may have had on inductive learning during the various study presentations.

Kost et al. (2015) found that interleaved order produced better categorization compared to blocked order during passive study when items were not repeated (their Experiment 3); however, when looking closely at their mean differences, performance was significantly lower than what was found here. Kost et al. observed a proportion recalled of roughly 0.70 following blocked presentation, and 0.80 following interleaved presentation (exact means were not provided in their report). The overall means reported here were much higher than what they had found (See Table 1), hence the ceiling effect in the data. It is possible that the study of only 6 categories rendered the development of categorization rules during the initial study period relatively easy regardless of whether items were presented first in either blocked or interleaved order. This could have affected learning such that individuals may have been able to equally distinguish between categories using similar categorization rules after initial study regardless of presentation order. Therefore, the advantage lies in viewing items in interleaved order when items are repeated, suggesting that the encoding of between-category differences and within-category similarities did not differ during the first presentation, but the rehearsal of these discriminations during repeated study did. Similar to Kost et al.’s assumption, repeated blocked presentation may not have provided individuals with enough between-category variability to encourage continued study of each painting. Meanwhile, the presentation of
interleaved order provided enough variability, regardless of whether items were encoded first in blocked or interleaved order, to encourage learners to attend to the features of each painting. This would result in additional rehearsal of categorization rules during a second period of interleaved study, which would have benefitted learning compared to blocked study, during which rehearsal was not as frequent during the second study period.

Bjork and Benjamin (2011) argued that interleaved study enhances learning and transfer of categorization rules to novel examples, because it forces learners to consistently retrieve these rules when items are interleaved. It is much more difficult to remember the rules for categorizing Braque paintings if the paintings are interleaved with other artists’ works. If learners view a Braque painting, then a Pessani painting, then a Juras painting, before viewing another Braque painting, they must retrieve the categorization rules for Braque paintings each time a Braque painting is viewed. Meanwhile, blocked presentation does not force the learner to retrieve the categorization rules to the same extent, as the successive presentation of Braque paintings would not require as much effort to retrieve the categorization rules learned in earlier presentations. This frequent rehearsal during the second period, as afforded by interleaved presentation, may be responsible for the observed increase in performance for both the interleaved-only and combined presentation conditions compared to the blocked-only condition. Thus, the findings presented here suggest that it may be the presentation order during the second study period which ultimately determines the effectiveness of rehearsal on learning of categorization rules.
However, as previously stated, this finding may largely depend upon the difficulty of the task, since the proportion recalled suggests that categorization was relatively easy using the 6 artists chosen. Kost et al.’s (2015) experiments were within-subjects designs and used a full collection of twelve artists. Therefore, participants completed separate tests: One following the study of six interleaved artists and one following the study of 6 blocked artists. Kost et al. did not discuss which artists were included in each set, nor did they reveal if artists were randomly assigned to each condition for each new participant. Therefore, while the 6 artists used in the present study were randomly chosen from the original collection of twelve artists, it is unknown whether these artists were ever used as a set during Kost et al.’s study. This is important to mention when comparing the present results to Kost et al.’s results in terms of proportion recalled. As previously stated, Kost et al.’s previous research on passive study found that their interleaved condition outperformed their blocked condition following a single study session. Their average proportion recalled was much lower than what was observed here; however, without knowledge of which artists were presented, it is impossible to know if the ceiling effect observed in these data is a result of the artists chosen, or the presence of study repetition. Furthermore, a repeated measures design might produce a decrement in performance as the experiment continues. While the conditions were counterbalanced, it is possible that studying and being tested on the first set of 6 artists could negatively affect performance during the second set. This could be due to fatigue experienced during the first study and testing sessions. To answer these questions, a future experiment would need to investigate categorization following a single study session, to determine if it is simply the artists chosen that facilitated such high proportions recalled.
A future study featuring a reversed combined presentation would also need to be conducted. If it is truly the presence of interleaved order during the second study session that determines the effectiveness of categorization rule rehearsal, and if this effect is not dependent upon the ease of the task, then presenting paintings in interleaved order first then blocked order, should result in similar outcomes to the blocked-only presentation order here. In addition to this, increasing the number of categories studied might be needed to reduce the ceiling effect observed here. With the inclusion of additional categories, thus increasing the difficulty of forming between-category rules for categorization, future research can determine if there is a difference between combined and interleaved-only study, and if not, future research can rule out the assumption that this may be due to the similarity of interleaved order during repeated study.

Overall, the results in this study suggest that combined presentation is an effective method for inductive learning when compared to blocked-only presentation; however, initial results suggest that it is not more effective than interleaved presentation. The advantages of interleaved and combined study were observed during testing of both previously viewed paintings and novel paintings of the same artists. This suggests that both interleaved and combined study allow for greater recall for the categorization of previously studied items, while also allowing for the categorization rules utilized during that recall to be transferred to novel paintings by the same artists. While overall performance was notably high, the differences observed between blocked presentation and the other two presentation methods were significant enough to suggest that these outcomes would be maintained if the number of categories were increased. In addition, the 6 artists included in this study were randomly chosen from the list of 12 artists.
provided in the original stimulus set originating from Kornell and Bjork (2008). Thus, it is possible that choosing 6 artists whose styles more closely resemble each other may make discriminations between categories more difficult, thus reducing the ceiling effect in performance. Either method of increasing difficulty would be necessary to further determine the effectiveness of combined study. It is possible that increasing the difficulty of the task might allow for differences between interleaved and combined study to become apparent. However, using the data presented here, it can only be hypothesized that the similar outcomes between interleaved and combined presentation are a result of the presence of interleaved order during the second period for both presentation methods.

Based on the results presented here, both combined and interleaved presentation orders are effective methods for improving inductive learning. By implementing a repeated study design, evidence was able to support that interleaved presentation benefitted both the learning of categorization rules and the extension of those categorization rules to novel members. Thus the present study was successful in extending Kost et al.’s (2015) finding that interleaved presentation benefitted learning when compared to blocked presentation during single session, passive study. However, a follow-up study is needed to attempt to replicate Kost et al.’s findings during a single study session, as the present study reported here may have used a different set of 6 artists in its independent samples design and thus altered the degree of similarity between each of the categories.

Additional research must also be conducted to determine any potential benefit of combined study over interleaved study, but the advantage of combined and interleaved presentation over blocked study is clear. Combined study, specifically that which
involved blocked presentation followed by interleaved presentation, may be particularly beneficial when study is repeated over time, as it produces additional attentional demand when items are repeated. This study serves as the first known testing of a combined approach. The advantages observed for combined over blocked study suggest that this combined approach is worthy of additional investigation to determine the extent to which it may be applied to increase long-term retention during inductive learning. However, any additional benefit that combined study might have over interleaved study must also be investigated with further research.
REFERENCES


Table 1

*Mean Proportion of Paintings Correctly Categorized and Standard Deviations as a Function of Presentation Order.*

<table>
<thead>
<tr>
<th>Paintings Recalled</th>
<th>Overall</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Total</td>
<td>0.912</td>
<td>0.125</td>
<td>0.857</td>
<td>0.139</td>
<td>0.937</td>
<td>0.114</td>
<td>0.943</td>
<td>0.105</td>
</tr>
<tr>
<td>Previously Viewed</td>
<td>0.924</td>
<td>0.114</td>
<td>0.875</td>
<td>0.127</td>
<td>0.951</td>
<td>0.101</td>
<td>0.946</td>
<td>0.099</td>
</tr>
<tr>
<td>Novel</td>
<td>0.895</td>
<td>0.150</td>
<td>0.830</td>
<td>0.169</td>
<td>0.916</td>
<td>0.139</td>
<td>0.938</td>
<td>0.150</td>
</tr>
</tbody>
</table>

*Note.* $N=40$ for each cell for Blocked, Interleaved, and Combined conditions. $N=120$ for the overall means and standard deviations.
Figure 1. Mean proportion of paintings correctly categorized as a function of presentation order and painting type.
APPENDIX A

STIMULI

Georges Braque Paintings
Henri-Edmond Cross Paintings
Judy Hawkins Paintings
Philip Juras Paintings
Ryan Lewis Paintings
Bruno Pessani Paintings
APPENDIX B

EXPERIMENT INSTRUCTIONS

1. General Instructions: In this experiment, you will be learning about a series of artists by viewing examples of their paintings. After studying these items, you will complete a brief counting task, and then you will be tested on your memory of the artists and their paintings. It is important that you follow all of the instructions that I give you throughout the experiment. You will be asked prior to the completion of each phase if you have any questions, so please do not hesitate to have me clarify any parts of the study that you may not understand.

2. Study Phase Instructions: First, you will learn about twelve different artists by viewing examples of their works. During this phase, you will see a painting displayed in the center of the computer display. Below the painting will appear the name of the artist who created the painting. Each painting-artist pair will appear on the screen for 3 seconds before the next painting and artist are automatically displayed. You do not need to press anything or respond in any way during this study phase. The study presentation will be repeated once during this phase. Once all of the items have been viewed, the display will automatically present the series of paintings and artists’ names again. You may study the items using any method you wish, by focusing on the qualities of the paintings that best help you learn each artist’s style. Do you have any questions
3. Distractor Task: Counting Backwards Instructions: In this phase of the experiment, you will first be given four single-digit numbers to remember. Once you’ve been provided these numbers, you will be asked to press the space bar to begin the counting backwards task. During this task, a three-digit number will be displayed on the computer monitor for three minutes. During this time, you are to count backwards aloud from this number by 3s. For example, if the number were 345, you would begin by saying 342, then 339, and so on. If you say a number that does not belong in the sequence, do not try to go back and correct your mistake. Instead, continue counting backwards by 3s from the number you provided. At the conclusion of the three minutes, you will be asked to recall the four-digit number you were originally provided before you began the counting backwards task. Do you have any questions?

The four digits that you are to remember are: 6-4-9-2

Notes for Researcher: Guide the participant during the task. Do not let them get “stuck” on a number. If they provide an incorrect number in the sequence, remind them to simply continue the sequence from there, rather than trying to say the correct number.

[Once 3 Minutes Have Elapsed] Do you remember the four digits?

4. Test Phase Instructions: We are now going to move onto the test phase of the experiment. In this phase, you will be tested on how well you remember each artist. During this test, you will see a painting appear in the center of the computer display. Below the painting will appear the names of the twelve artists you had previously learned. At this time, you are to use the mouse to click on the name of the artist that you think created the painting. You have as much time as you need to click on a name. If you do not know the name of the artist who created the painting, we ask that you make your
best guess based upon what you can remember about the artist and their work. Do you have any questions before you begin the test?

5. Conclusion: You have completed the experiment. Thank you for your participation.

*Note for Researcher: At this point, you should give the participant the debriefing form and walk them through the overall objectives of the study. Answer any remaining questions that the participant may have.*