Effects of blocked versus interleaved presentation on children's vocabulary learning:

A pilot study

Nicole L. N. Tan

Dorothy V. M. Bishop

Adam J. Parker*

Affiliations:

Department of Experimental Psychology, University of Oxford, Anna Watts Building,
Radcliffe Observatory Quarter, Woodstock Road, Oxford OX2 6GG.

*Correspondence regarding this article should be addressed to Adam J Parker, Department of Experimental Psychology, University of Oxford, Anna Watts Building, Woodstock Road, Oxford OX2 6GG, UK. Email: adam.parker@psy.ox.ac.uk

Abstract

In some educational contexts, it has been shown that interleaved presentation (i.e. alternating different tasks/skills) results in better learning than blocked presentation (i.e. practising one task/skill at a time). However, this interleaving effect has been studied in a limited range of contexts. Here, we examined whether blocked versus interleaved presentation influenced vocabulary learning in 56 children aged from 6 to 10 years old. We devised a novel online game involving two tasks. The first was a vocabulary learning task, in which children matched spoken words to images of novel animals. The second was a comprehension task, where the children arranged objects to match the spatial relations described in a spoken sentence. Stimuli were presented in a between-subjects design, such that trials from each task either occurred in blocks of 10 or were fully interleaved. Our analysis revealed vocabulary learning in both conditions, but the rate of learning did not differ for participants assigned to the blocked vs interleaved conditions. We did not, however, use posttest assessment means, so we cannot rule out any benefit of interleaving that may emerge after the initial learning phase.

Acquiring knowledge takes time and effort. But which is more effective: learning in one domain at a time or learning in multiple domains concurrently? Blocked practice (i.e. learning in one domain at a time) seems the intuitive answer, given the ease of administration and the fact that at any given time learners need only focus on mastering one domain of expertise. However, there is growing evidence that interleaved practice (i.e. learning in multiple domains concurrently) can have benefits over blocked practice for a diverse range of domains (for reviews see Kang, 2017; Rohrer, 2012). Nevertheless, a recent statistical synthesis of 59 studies conducted by Brunmair and Richter (2019) challenged the notion that interleaved presentation always leads to superior learning. While this meta-analysis highlighted the strength of interleaved presentation when learning visual materials, the evidence was less clear when learning verbal materials. Additional evidence suggests that blocked presentation appears more efficient for vocabulary learning (Finkbeiner & Nicol, 2003; Schneider, Healy, & Bourne, 1998, 2002; Sorensen & Wotlz, 2016) while interleaved presentation may benefit grammar learning (Nakata & Suzuki, 2019; Pan, Tajrana, Lovelett, Osuna, & Rickard, 2019). It is important to note that these findings were based on experiments involving only adult participants. As such, the potential benefits of interleaved presentation on children's learning of vocabulary and grammatical rules remains relatively unexplored. This is the focus of the current study.

To reiterate, under blocked presentation, only a single skill or material is practised/learned at any given time (e.g. AAAABBBB). In contrast, under interleaved presentation, two skills/types of materials are practised/learned together in an alternating fashion within a session (e.g. ABABABAB). The benefits of interleaved presentation are illustrated in a study conducted by Kornell and Bjork (2008) who trained participants to distinguish impressionistic paintings of landscapes by 12 artists. Participants saw six

exemplar paintings by six of the 12 artists in a blocked condition and six exemplar paintings by the remaining six artists in an interleaved condition. Paintings were presented for 3 seconds along with the artist's name. After a learning phase where participants familiarised themselves with the style of each artist, participants assigned new paintings to each of the 12 artists. Kornell and Bjork reported greater accuracy in assigning paintings to artists for whom exemplar paintings had been shown in the interleaved condition. This interleaving effect has been replicated numerous times when using the same stimuli (Metcalf & Xu, 2016; Kang & Pashler, 2012; Kornell, Castel, Eich, & Bjork, 2010; Verkoeijen & Bouwmeester, 2014; Zulkipli, 2015; Zulkipli, & Burt, 2013a, Zulkipli & Burt, 2013b).

While interleaved practice appears effective for learning to discriminate between types of impressionistic landscapes, the evidence base is somewhat less conclusive for other types of visual stimuli. Studies using artificial visual stimuli (e.g. 20 x 20 cell multi-coloured grids) report positive results of interleaving (Higgins & Ross, 2011; Lavis & Mitchell, 2006; Mitchell, Nash, & Hall, 2008), but these results appear weaker when categories are highly discriminable (e.g. Zulkipli & Burt, 2013a) or when the classification of stimuli requires rule-based learning (Noh, Yan, Bjork, & Maddox, 2016). Furthermore, interleaved practice yields mixed results when learning expository texts (Zulkipli & Burt, 2013b) and mathematical tasks (Taylor & Rohrer, 2010; Higgins & Ross, 2011). The evidence base of language tasks is mixed as well, with different domains demonstrating different effects of blocking/interleaving. Specifically, interleaving appears to be detrimental when learning pronunciations (Carpenter & Mueller, 2013), mixed when learning vocabulary (Finkbeiner & Nicol, 2003; Schneider, Healy, & Bourne, 1998, 2002; Sorensen & Wotlz, 2016), and beneficial when learning grammar (Nakata & Suzuki, 2019; Pan, Tajran, Lovelett, Osuna, & Rickard, 2019).

Regarding pronunciations, Carpenter and Mueller (2013) had English-speaking adults learn pronunciation rules for French. In the blocked condition, participants were exposed, both orally and visually, to one sound at a time (e.g. *bateau*, *fardeau*, *rameau*,... *darder*, *combler*, *valser*...). In the interleaved condition, the words were presented in an interleaved fashion (e.g. *bateau*, *darder*...). Across four experiments, participants' pronunciation proficiency was assessed through multiple-choice tests or a recall task, and in all experiments, blocking benefitted learning more than interleaving. For instance, in Experiment 1, accuracy for previously-practised whole word pronunciations was 56% in the blocked condition and 44% in interleaved condition. For new words, accuracy was 46% in the blocked condition and 42% in the interleaved condition. The benefits of blocking here can be explained by two moderating factors. First, because pronunciation rules were markedly different, the between-category discriminability was high. According to the *discriminative contrast hypothesis* (Carpenter & Mueller, 2013; Kang & Pashler, 2012), the benefits of interleaving occur as presenting different exemplars in succession enables learners to identify differences between items more easily. Consequently, this benefit would theoretically be strongest when the intuitive between-category discriminability is low. A second explanation is that the beneficial effects of interleaving were absent in this study because the learners had no prior knowledge of French pronunciations, and blocking tends to be more effective than interleaving for complete novices (e.g., Guadagnoli, Holcomb, & Weber, 1999).

Studies investigating vocabulary learning have considered whether blocking by semantic category is beneficial. For instance, Finkbeiner and Nicol (2003) had 24 participants learn 32 pseudowords that belonged to four semantic categories (animals, body parts, furniture, and kitchen utensils), with presentation either blocked or interleaved according to semantic category. After a learning phase, during which they were required to repeat the

name of a novel pictured item, participants completed a translation task. Contrary to the expectation that blocking would be better for learning new words with no prior experience, Finkbeiner and Nicol reported faster reaction times for items studied in the interleaved condition. In contrast, Schneider et al. (1998, 2002) failed to establish any benefit of interleaving semantic categories during practice for vocabulary learning. Schneider et al. (1998) had English-speakers learn 25 French words belonging to one of five semantic categories under blocked or interleaved presentation. While blocked presentation resulted in greater accuracy during an initial learning phase, no benefit was found for either blocked or interleaved presentation at a 1-week posttest. A similar pattern was reported by Schneider et al. (2002) where blocking resulted in higher scores on immediate testing but no clear benefit was found in a 1-week delayed posttest. Collectively, these studies highlight the importance of blocking during learning and also demonstrate that the lasting benefits of a presentation mode may fade with time. This points to the need for post-test assessments in order to uncover lasting effects on learning.

It is important to note that the studies reviewed thus far all implemented blocking and interleaving throughout the whole training phase. Sorensen and Woltz (2016) combined blocked and interleaved presentation and reported that better learning of verbal categories in a hybrid condition compared to a condition that employed interleaved presentation alone. Thus, vocabulary learning appears optimised when an initial blocked phase is used to anchor newly learned words and an interleaved session provides the opportunity to contrast items to maximise learning (c.f. Carpenter & Mueller, 2013; Kang & Pashler, 2012). The authors argue that for some learning tasks, and particularly those involving explicit rule learning, using interleaving too early disrupts the cognitive processes that are necessary to develop a complete understanding of the categories being learned (i.e. working memory, attention,

hypothesis testing). An alternative argument is that immediate interleaving results in confusion between rules and concepts, which leads to reduced learning (Kurtz & Hovland, 1956).

Investigations of blocked versus interleaved presentation on adults' grammar learning have yielded somewhat positive results. Across four experiments, Pan et al. (2019) trained English-speaking participants on two Spanish grammar rules under blocked or interleaved presentation. In Experiments 1 and 2, Pan et al. presented items in a single session and reported no significant difference between blocked versus interleaved presentation during a test phase. In Experiments 3 and 4, presentation occurred over two sessions which were separated by 1-week. In the blocked condition, participants learned one rule in week 1 and a second rule in week 2. In the interleaved condition, they learned both rules during weeks 1 and 2. The data here clearly indicated that interleaving benefits grammar learning across multiple training sessions. Another study, conducted by Nakata and Suzuki (2019), provides further evidence in support of an interleaved presentation for grammar learning. In their study, 115 Japanese-speaking participants learned five grammatical structures under blocked, interleaved, or increasing (i.e. blocked followed by interleaved) presentation. Learning was assessed using a grammaticality judgement task that was either administered immediately after a training phase or at a 1-week follow-up. Despite the clear benefits of blocked presentation for learning-phase accuracy, no statistically significant difference was found between the presentation conditions during an immediate posttest. The 1-week posttest indicated that interleaved presentation yielded superior accuracy (as indexed by d' primes) compared to blocked presentation, yet there was no statistical difference between performance in the interleaved and increasing conditions or the blocked and increasing

condition. Taken together, these results suggest that interleaved presentation may be somewhat beneficial to the learning of grammatical structure but not for vocabulary learning.

To date, there are surprisingly few studies investigating the effects of blocked versus interleaved presentation on children's learning. Studies examining the effects of age on the interleaving effect have reported that the beneficial effects of interleaved presentation do not differ between younger and older adults when learning visually complex paintings (Kornell, Castel, Eich, & Bjork, 2010). In contrast, studies of motor sequence learning report interactions between interleaving and age-group, indicating that younger adults benefit more from interleaving than older adults (Lin et al., 2012). Interestingly, the functional magnetic resonance imaging data reported by Lin et al. suggested that interleaved presentation of motor sequence learning is associated with the activation of a more efficient brain network for younger adults. Yet another study that examined category learning in young (2-year-old) children indicated that blocked presentation yields better performance at posttest (Sandhofer & Dumas, 2008), implying that blocked presentation may prove more beneficial for learning of categories in younger children compared to adults. Together these results demonstrate that the interleaving effect may change over the life span, meaning that blocked presentation may prove beneficial for the learning children.

In the studies reviewed above, the learning task was kept constant for all trials, with blocking and interleaving being defined according to item characteristics such as the semantic category of a learned word, or visual characteristics of artistic style. This approach has led to theoretical accounts of blocking/interleaving effects that focus on the discriminability and confusability of items in two or more categories. There has been less attention to blocking effects when item sets are more radically different, though this could be of educational relevance. If a child has to learn new information in more than one domain, then blocking

could be advantageous in helping the learner develop a ‘task-set’, but interleaving may serve to avoid boredom, by increasing trial-by-trial variability of items, and requiring continual reorientation of attention. There is thus a potential trade-off between focusing on a particular type of task (i.e. blocking), and shifting back and forth between tasks (i.e. interleaving).

Research questions and hypotheses

From the aforementioned literature, it is clear that the interleaving effect differs in direction for a variety of tasks. Our original goal was to examine how blocked versus interleaved presentation influences the learning of vocabulary and the comprehension of reversible sentences in children using an online game that adopted an errorless learning procedure. However, to retain children’s interest and avoid ceiling effects, we varied the difficulty level of the sentence comprehension task across sessions, according to how well the child was performing. We decided therefore to treat the sentence comprehension task as a ‘filler’ task and focus our analysis on the effect of blocking/interleaving on vocabulary learning. In this regard, the analysis reported here differs from our pre-registered plan, where we had intended to look at learning effects on both tasks.

We compared performance across blocks to examine two research questions: (1) with repeated exposure to stimuli, would children show evidence of learning; and (2) would blocked or interleaved presentation (of the vocabulary and sentence comprehension tasks) influence the learning of vocabulary? Based on the reviewed literature, we predicted the following:

- (1) Regardless of presentation mode, children would show evidence of learning, i.e. when comparing performance on later blocks to performance on early blocks, accuracy should be greater and reaction times should be shorter.

- (2) Learning of vocabulary items would be superior when the items were presented in blocks (i.e. blocked presentation), then when vocabulary items are interleaved with sentence comprehension items.

The prediction of superior performance with blocked presentation would be compatible with prior research showing that blocked presentation is favourable when initially learning a skill (Kang & Pashler, 201; Rohrer & Taylor, 2007; Taylor & Rohrer, 2010). We note, however, that generalisation from prior literature may not apply, given that we interleaved quite different tasks (vocabulary learning and sentence comprehension), whereas most prior literature has varied only item content and similarity.

Methods

This experiment was pre-registered on the Open Science Framework prior to the commencement of data collection. The registration form, data, and R scripts can be found at <https://osf.io/ykacn/>. As noted above, analysis of learning of sentence comprehension items was not appropriate given the increasing difficulty of the task, and so the final analysis was simplified to include only learning on vocabulary items. Scripts for the final analysis are available at the same site.

Participants

An initial sample of 96 children, aged 6- to 10-years old ($M_{\text{age}} = 8.2$ years; $SD_{\text{age}} = 1.55$ years), took part in the study. Children were contacted with the consent of parents who were informed of the study's purpose. Children were native English speakers, UK residents, naive to the study's purpose, and their parents did not report any history of reading/language impairment, autism, or attention deficit hyperactivity disorder. As explained further below, the final analysis was conducted on 56 children who had completed sufficient trials for analysis.

Ethical approval for this study was granted by the University of Oxford's Medical Sciences Inter-Divisional Research Ethics Committee (Approval Number: R64396/RE001). The experiment was undertaken with the understanding and assent of each child.

Online task

Children participated in a task developed on the Gorilla platform (<https://gorilla.sc/>; Anwyl-Irvine, Massonnié, Flitton, Kirkham, & Evershed, 2020). For all trials, in response to spoken stimuli, children positioned objects within a grid. Correctly placing objects enabled children to progress through a cave to accumulate treasure. Two different types of spoken stimuli were used (see Figure 1): rare (unfamiliar) animal names for the vocabulary task and spoken sentences that compared spatial relationships between objects for the sentence comprehension task. These stimuli formed the basis of our vocabulary and comprehension tasks that were used to compare the effects of blocking and interleaving.

Figure 1. Illustration of the vocabulary task (left) and comprehension task (right). For the vocabulary task, children would hear “hoatzin” and position an object from the array at the bottom of the screen into the open grid square until they identified the correct object. For the comprehension task, children would hear “the wheel is above the bat” and position objects from the array below into the open grid squares until the wheel was placed into the grid square above the bat.

Vocabulary task

Children learned a set of ten rare animal names (anole, aye aye, caiman, dugong, fossa, hoatzin, iiwi, jennet, kyloe, saki). Bishop and Hsu (2015) previously demonstrated that these words were highly unlikely to be known by children. We trained understanding of real words, as we planned to extend the training to children with language difficulties, where our use of nonsense words would be ethically questionable. Use of real words limits experimental control over items, but all animal names were selected to be distinctive, bisyllabic, and had a spoken duration of 800-1010 ms duration. The names had a mean Zipf frequency of 2.5 from the CBBC portion of the SUBTLEX-UK database (Van Heuven, Mandera, Keuleers, & Brysbaert, 2014). Over the course of the experiment, each of the ten unique items was displayed in pseudo-randomised order across five blocks. In contrast to Bishop and Hsu (2015), there was no initial learning phase. Learning occurred via exposure and feedback (see Procedure below).

Sentence Comprehension task

Children were presented with five blocks of 10 unique sentences containing either *above/below*, *between*, or *above/below/next to*. Each block related to a level of difficulty whereby the number of objects to be placed within the grid, the number of fixed objects at the start of the trial, and the prepositions used, varied (see Table 1). We varied the difficulty in this task to retain the interest of the children, as previous reports indicate that typically developing children tend to perform at ceiling on similar tasks that require children to respond to simple sentences such as “*the hedgehog is above the boot*” (Hsu & Bishop, 2014). A total of 35 nouns were used when constructing the sentences. The nouns were monosyllabic and high frequency ($M_{\text{zipf}} = 4.6$). The spoken stimuli ranged from 1900-4700 ms in duration. Each of the unique items was pseudo randomised within each block.

Table 1. Example sentences for the comprehension task.

Level	No. objects to be placed	No. fixed objects	Prepositions	Example
1	1	1	<i>above, below</i>	<i>The boat is below the scarf.</i>
2	2	0	<i>above, below</i>	<i>The shirt is above the door</i>
3	2	1	<i>between</i>	<i>the hen is between the star and the flag</i>
4	2	1	<i>between</i>	<i>The car is between the hen and the clock</i>
5	2	1	<i>above, below, next to</i>	<i>The bed is next to the tree and the jug is below the tree</i>

Blocking and interleaving

Blocking/interleaving was between-subjects, with children pseudo-randomly assigned by the Gorilla programme to a blocked or interleaved condition, ensuring equal numbers in each group. In the interleaved condition, children completed alternating trials of vocabulary and comprehension stimuli. In the blocked condition, children were presented with alternating blocks of 10 vocabulary items and 10 comprehension items. This was done to ensure that, even if children did not complete all the test items, we would have sufficient data from both item types for analysis.

Procedure

Children completed the task online in a quiet place of their choosing, in a single session. Parents were asked to supervise the children and provide encouragement. Children were instructed to wear headphones when completing this task on a touch-screen tablet or a laptop/desktop computer to reduce the likelihood of parental assistance.

A game-like format using an errorless learning procedure was used. At the start of each trial, children would hear a stimulus. They would then position the corresponding

object(s) into the appropriate grid cell(s). If a correct response was made, there would be an auditory reward and a visible reward; a new gem would appear and be added to the child's treasure collection. If an incorrect response was made, the object would return to the array and the auditory stimuli would be replayed. For each trial, accuracy was recorded as 0 or 1, with 1 indicating that children had correctly positioned the object(s) from the array into the appropriate grid cell(s) on their first attempt. The number of attempts made to correctly arrange the objects and the time taken (in milliseconds) to complete each trial (response time) was also recorded. Example trials and stimuli are available via the following link:

<https://bit.ly/3j5rhxC>.

The testing session was limited to 20 minutes. If a child had not completed all trials within this time frame, the experiment automatically terminated. While this ensured that children remained motivated for the duration of the experiment, many failed to complete the number of items that was sufficient for inclusion in our analysis. We discuss this in due course.

Data analyses

Prior to statistical analysis, we applied the following data cleaning procedures. For reaction time analysis, we considered correct responses only (i.e. those that were correct on the first attempt). We removed trials where reaction times were below 200 ms or greater than 20,000 ms. We then identified outliers using Hoaglin and Iglewicz's (1987) procedure. For each child, the difference between the first and third quartiles of their reaction times was calculated. Outliers were defined as having a reaction time that was more than 1.65 times this difference above the third quartile or 1.65 times the difference below the first quartile. Outliers were removed from the analysis.

Data analysis

We had pre-registered an analysis using linear mixed-effects models to examine the impact of task-type (vocabulary/sentence comprehension) and presentation condition (blocked/interleaved) on learning. However, as noted above, in practice, our task design made it impossible to look at learning in the sentence comprehension task, and so it was treated as a filler task. Furthermore, few children (32%) completed all five blocks of the vocabulary items (see Table 2). To maximise the number of children available for analysis while maintaining a number of blocks that were sufficient to estimate learning, we chose to analyse the data for 56 children who completed four blocks of vocabulary items. Thirty-two of these participants were allocated to the blocked condition and 24 to the interleaved condition. For these children, we considered only the first 40 vocabulary items. As this resulted in a smaller dataset than we had originally anticipated, we conducted a simpler statistical synthesis of the data.

Table 2. Count of participants against the number of blocks completed. Each block contains 10 vocabulary items.

Number of complete blocks	N
1	96
2	96
3	76
4	56
5	31

To assess learning on the vocabulary items, we analysed the number of attempts and reaction times: learning would be indexed by a smaller number of attempts and faster reaction times. For the number of attempts, we used beta-estimates/regression weights to estimate

learning. This was achieved by fitting a Poisson generalized linear model to count data for each child, where a continuous numeric variable coding block number predicted the number of attempts to produce a correct answer on each trial. This resulted in a single beta-weight per child, where a negative beta-estimate indicated a negative slope, i.e. learning. We then conducted a series of one-sample t -tests to assess whether the individual beta-estimates were significantly less than zero in the blocked and interleaved conditions. For reaction times, we adopted a similar approach. For each participant, we first identified the median reaction time in each block. We then fit a linear model to log-transformed reaction times to produce a beta-estimate for each child, again using a continuous numeric variable coding block number to predict log-transformed median reaction time for each block. A one-sample t -test was used to assess whether the beta-estimates were significantly less than zero in the blocked and interleaved conditions.

To examine the effects of blocking/interleaving on vocabulary learning, we conducted a series of independent-samples t -tests. The first compared the beta-estimates for the number of attempts between presentation conditions. The second compared the beta-estimates for log-transformed reaction times between presentation conditions. To assess the evidence for critical null effects, we supplement our analyses with Bayes-Factor analysis (see Wagenmakers, 2007, for a review). Bayes factors were computed Using the `ttestBF()` function from the `BayesFactor` package in the R environment (Morey & Rouder, 2018), with 100,000 Monte Carlo iterations. All models assumed the default Cauchy prior for effect size.

Summary of departures from pre-registered analyses

In sum, our analyses departed from our pre-registration in the following ways:

- (1) We analysed only vocabulary items as the increasing difficulty of the sentence comprehension items were inappropriate for indexing learning;

- (2) We analysed data for children who completed four or more blocks of the vocabulary items. In these cases we analysed only the first 40 items;
- (3) Learning was assessed by obtaining beta-estimates for each child and then conducting a series of one-sample *t*-tests which compared dependent measures at the population level with zero;
- (4) We compared the effect of blocking/interleaving through a series of independent-sample *t*-tests and supplemented these analyses with Bayes Factor analysis.

In Figure 2, the statistical power for a one-sample *t*-test and an independent-samples *t*-test are shown for a range of effect sizes and are presented to aid interpretation of our statistical analyses. From Figure 2, we can see that 24 participants would provide >80% power to detect an effect size of $d = .5$ when conducting a one-sample *t*-test. The current sample would provide >40% power to detect an effect size of $d = .5$ when conducting an independent-samples *t*-test.

Figure 2. Power contour plots for (A) the one-sample t -test to assess learning (i.e. beta-estimates against zero) and (B) the independent samples t -test for the comparison of dependent measures in the blocked and interleaved conditions. The range of effect sizes are shown on the y-axis and sample size is shown on the x-axis.

Results

The mean number of attempts and reaction times across the four blocks in each of the tasks and experimental conditions are shown in Figure 3 across the four blocks. The data for sentence comprehension confirm that performance was close to ceiling (the mean number of attempts were close to one), and reaction times increased at the final block, which included more difficult grammatical constructions. The vocabulary task did not suffer from these limitations, and Figure 3 indicates a reduction in the number of attempts and the reaction times across the four blocks.

Figure 3. (A) mean number of attempts and (B) mean reaction times for comprehension and vocabulary items across the four blocks. Scores in the blocked condition are indicated by pink lines while scores in the interleaved condition are shown in blue. Error bars represent 95% confidence intervals around the mean.

Learning

At the population level, Figure 4 indicates that there was learning for vocabulary items in both the blocked and interleaved conditions. A one-sample t -test confirmed that the beta-estimate for the number of attempts was significantly less than zero in the blocked, $t(31) = -7.12$, 95% $CI = [-0.14, -0.08]$, $d = 1.26$, $p < .001$, and the interleaved, $t(23) = -6.60$, 95% $CI = [-0.15, -0.09]$, $d = 1.35$, $p < .001$, conditions. A similar pattern emerged for reaction times where beta estimates were significantly less than zero in the blocked, $t(31) = -4.50$, 95% $CI = [-0.05, -0.02]$, $d = 0.80$, $p < .001$, and the interleaved, $t(23) = -2.33$, 95% $CI = [-0.04, < -0.01]$, $d = 0.48$, $p = .029$, conditions. Taken together, these results indicate that our online game was able to index learning.

Figure 4. (A) beta-estimates for number of attempts and (B) beta-estimates for median reaction times for vocabulary items in the blocked and interleaved conditions. Data points represent estimates for individual participants. Red dots indicate scores in the blocked condition and blue dots indicate scores in the interleaved condition. The notch on the box plot reflects the mean in each condition. The dashed black line marks zero. Scores less than zero indicate learning.

Blocking/interleaving

The independent-samples t -test comparing beta-estimates for the number of attempts indicated that beta-estimates did not differ between the blocked and interleaved conditions, $t(50.92) = 0.09$, 95% $CI = [-0.04, 0.05]$, $d = 0.02$, $p = .926$. The Bayes Factor for the alternative model was 0.27 when compared against a null model. Based on Jefferys (1961) suggestions for interpretation, the data provide moderate evidence for the null hypothesis, indicating that the reduction in the number of attempts across the four blocks did not differ between the blocked and interleaved conditions. For reaction times, the beta-estimates did not differ between the blocked and interleaved conditions, $t(48.94) = -1.12$, 95% $CI = [-0.03, 0.01]$, $d = 0.30$, $p = .270$. The Bayes Factor for the alternative model was 0.46 when compared against a null model. This is taken as anecdotal evidence for the null hypothesis, indicating that the

reduction in median reaction times across the four blocks did not differ between the blocked and interleaved conditions.

Discussion

We set out to examine how blocked and interleaved presentation influenced the learning of vocabulary in children. This was accomplished by implementing a novel online game, in which novel vocabulary items were either presented in blocks or interleaved with sentence comprehension items. Due to ceiling performance on the comprehension items coupled with the increasing difficulty of the comprehension stimuli our analyses focused only on vocabulary items. First, we report that our novel game can index learning under both blocked and interleaved presentation. Second, the rate of learning did not differ under blocked or interleaved presentation. We discuss the importance of these findings in turn.

Learning

Word learning is complex, dynamic, and evolves over repeated exposures (McGregor, Friedman, Reily, & Newman, 2002). When learning spoken words, the task is to bind a label to a referent. In the current study, this would mean binding “*hoatzin*” to the image of a bird, which requires a well-formed representation of the phonology associated with the label to ensure that it will not be confused with similar-sounding words. This also means understanding enough about the semantics of the referent to be able to appropriately understand the word in context. To statistically examine associative word learning in the current study, we fit linear models to the numbers of attempts and reaction times across blocks for each participant. This resulted in a beta-estimate for each participant, where a negative beta-estimate indicated learning. At the population level, there was evidence of learning for both the number of attempts and reaction times, indicating that children were generally successful in associating phonological representations with their visual referents.

Blocking and interleaving

Several studies have suggested that interleaved presentation may be beneficial for inductive learning (Higgins & Ross, 2011; Kang & Pashler, 2012; Kornell & Bjork, 2008; Kornell et al., 2010; Rohrer & Taylor, 2007). However, other studies have found no positive effect of interleaved presentation (Carpenter & Mueller, 2013; Dobson, 2011; Higgins & Ross, 2011; Rau et al., 2010; Sorensen & Woltz, 2016). A recent meta-analysis (Brunmair & Richter, 2019) shed light on these mixed results revealing that interleaving is most effective when learning complex visual stimuli, and when the similarity between the interleaved concepts is high. Based on these findings, it might not be surprising then that we observed no benefit of interleaved presentation on children's vocabulary learning. The vocabulary task was markedly different from the comprehension task (i.e. low similarity between the interleaved concepts). The spoken stimuli used for the vocabulary task were single unfamiliar nouns, while the comprehension items involved a sentence including several familiar words. The two tasks also required very different responses. The vocabulary task required paired associations between spoken and visual stimuli while the comprehension task required children to interpret prepositions describing spatial relationships and to move visual stimuli to match the sentence. As such, there would be no difficulty distinguishing the two sets of stimuli/tasks, meaning that the ability to contrast stimuli with interleaved presentation may add no additional benefit. In this light, our results would be consistent with the discriminative-contrast hypothesis, which predicts that the effects of interleaving are greatest when the concepts to be learned are similar.

We also anticipated that some interleaving effects might nevertheless be observed if shifting task demands led to greater attention and reduced boredom, but there was no evidence for this. The observation that neither blocking or interleaving gave better learning

stands in contrast to prior research on vocabulary learning. Studies that have examined performance during a learning phase have reported a preference for a blocked presentation (Schneider et al., 1999, 2002; Sorensen & Volts, 2016) which is at odds with the current data. Several candidate explanations exist for this. The first is an issue of power. As shown in Figure 2b, we had a sufficient sample size to detect a standardised effect size of $d = 1.00$ with 80% power. The observed effects sizes were indeed much smaller for the comparisons between blocked and interleaved presentations on number of attempts and reaction times. This means that a larger sample size may have been necessary to identify an effect as statistically significant. A second explanation is that children may not immediately show a preference for blocked versus interleaved presentation for vocabulary learning. Instead, these effects may emerge only much later at posttest-- a feature not included in our design. Therefore, future research will need to explore the longer-term effects of blocked versus interleaved presentations on children's language learning by including posttest measures.

Finally, we note that, although our study involved vocabulary learning, the type of materials used for interleaving vs blocked presentation were very different from those used with adults, where items sets all used the same task, but varied in semantic relationships. Discriminability of items is an important dimension that may affect whether blocking or interleaving effects are observed in children, but our study was not designed to investigate this. Thus, in the future, there would be an interest in studying blocking/interleaving effects using only vocabulary items, with the different item sets varying in discriminability. This would allow us to examine whether the effects of interleaving can be observed in children's vocabulary learning when the differences between stimuli are more subtle compared to this study.

Summary and conclusions

In sum, this study utilised a novel online game to study the effects of blocked versus interleaved presentation on children's vocabulary learning. The game was engaging and the data indicates that children learned the stimuli; with repeated encounters of stimuli, fewer attempts were required for a correct response and children were quicker at making correct responses. Critically, the current study did not find evidence that blocking or interleaving led to increased learning. These results are suggestive in showing that children's learning is equivocal under these presentation types, but we cannot rule out the possibility that blocking versus interleaving may be beneficial to learning after initial exposure (i.e. in posttest measures), or when different stimulus materials are used.

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