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Young Children's Self-Directed Information Gathering on Touchscreens

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Abstract

Self-directed learning, defined as the ability to choose what to learn about, represents a unique educational opportunity. We test the effect of self-direction on learning outcomes in children (N=32, *age range*=3-5 years) in a novel word-learning task conducted via touchscreen tablets. Study participants were randomly assigned to one of two learning conditions: one in which learning was self-directed and one in which it was not. Children in the self-directed condition performed better on a recognition task, controlling for subject and item effects. Our results suggest that self-directed learning facilitates information retention in children, in line with previous work that has found improved information retention using self-directed learning paradigms in adults (e.g., Markant, DuBrow, Davachi, & Gureckis, 2014).

Keywords: Learning; cognitive development; developmental experimentation.

Introduction

The idea that people learn best from material that they select has been pervasive across the fields of education (e.g., Bruner, Jolly, & Sylva, 1976; Montessori, 1912; Piaget, 1930), developmental psychology (e.g., Berlyne, 1960), and cognitive science (e.g., Gureckis & Markant, 2012). Specifically, self-directed learning—defined here as the ability to choose what to learn about (see Gureckis & Markant, 2012 for a review)—can provide the learner with volitional control over order and timing of stimuli presentation, sequence of search decisions, and validating or refuting hypotheses.

Early research on self-directed learning largely considered its potential in adult learners (e.g., Brockett & Hiemstra, 1991; Brookfield, 1984; Tough, 1978). Some recent work has investigated the potential of self-directed learning in younger populations (e.g., Metcalfe, 2002; Nor & Saeednia, 2008); however, most focuses on evaluating whether self-directed learning benefits the academic performance of postsecondary students (e.g., Chou & Chen, 2008).

Touchscreen tablets have increasingly been utilized in primary and secondary classrooms, with many school districts providing tablets to all students. Yet quantitative research on the use of tablets for educational purposes has not yet carefully investigated specific causal mechanisms that might yield improved learning, instead investigating the effectiveness of content-related (e.g., writing, reading, spelling) applications in the classroom (e.g., Brown & Harmon, 2013). Work that directly investigates the mechanisms underlying self-directed learning—especially in young children—is extremely limited. This work is crucial because understanding how self-directed learning promotes better learning outcomes is key to designing better educational curricula that maximize children's learning potential.

One theorized mechanism posited for explaining the benefits of self-directed learning relates to *informational choice and pacing*. Allowing a learner to choose the order, duration, and temporal presentation of new information could boost learning because learners are theorized to have mechanisms that guide their attention towards material best-suited for learning (e.g., Berlyne, 1960; Dember & Earl, 1957; Kidd, Piantadosi, & Aslin, 2012, 2014; Kinney & Kagan, 1976; Piantadosi, Kidd, & Aslin, 2014). Studies with adults, for example, have demonstrated that they strategically select information that maximally reduces uncertainty about category boundaries (e.g., Bardhan, Aslin, & Tanenhaus, 2010; Markant & Gureckis, 2010) or reduces the hypothesis space during complex rule learning (e.g., Markant Gureckis, 2012). A common line of research along this theme in the education literature is the study of academic study time allocation in both adults (e.g., Metcalfe, 2002) and children (e.g., Dufresne & Kobasigawa, 1989). This line of research investigates how the decisions students make about what they study and how much time they devote to different topics affects learning outcomes. There is also evidence that children—like adults—direct their attention towards material that reduces uncertainty and improves learning (e.g., Schulz & Bonawitz, 2007). As an example, Bonawitz, van Schijndel, Friel, and Schulz (2012) demonstrated that children preferentially play with toys that violate their expectations.

Another theorized mechanism as to why self-directed learning leads to better learning outcomes is that it increases the *level of engagement* learners have with the learning material. Typically, these studies rely on either self-report or reports from educators in order to estimate learners' levels of engagement (e.g., Henderson & Yeow, 2012; Milman, Carlson-Bancroft, & Boogart, 2012) rather than objective, quantitative measures. Further, and more problematically, these studies do not directly test whether the increased levels of engagement themselves yield better learning outcomes.

Based on this previous literature, we would expect that self-directed learning should improve learning outcomes in young children. However, no previous study has quantitatively evaluated whether self-directed learning yields better learning outcomes controlling for the content of the information presented in children. In our study, we present the same information to two groups of young children (3- and 4-year-olds) and manipulate whether their learning is self-directed or not. In other words, all children see the same total amount of learning material, but half select which learning material they would like to hear directly.

Experiment

The aim of this study was to determine whether self-direction increased the retention of novel object-word pairings when tested on a touchscreen tablet. Participants were trained in one of two conditions: *choice* and *no choice*. The *choice* condition allowed participants to tap directly on the toy object while the participants in the *no-choice* condition could only tap a button in the center of the screen (see Figure 2). The button was present for both conditions to maintain visual consistency; however, it was grayed out in the *choice* condition to indicate it did nothing (see Figure 2 for difference). All participants were tested without parents in the room to avoid parental influence on children’s behavior.

Participants

We recruited 32 children (*M* = 3 years; 11 months, *range* = 3;0 4;11) from the Rochester Baby Lab database. Children were randomly assigned to either the *choice* condition or the *no-choice* condition (*N* = 16 per condition). The groups were matched in age and distribution of gender. All participants had normal hearing and vision, according to parental report, and heard at least 90% English in the home. Three children were excluded from final analyses because they had to leave the testing room unexpectedly (e.g., to use the bathroom) midway through the study (*N* = 3).

Materials

The study was run on an 11.6” Samsung Tablet PC Model XE700T1A running Ubuntu 14.04. The stimuli were photos of 15 novel toy characters that were randomly paired with novel two-syllable words that followed the phonotactic rules of English (Figure 1). The words were chosen to be maximally distinguishable, with phonologically distinct onsets and no repeated syllables. The toy characters were chosen as objects to be maximally interesting and engaging to the children. All stimuli were presented on the touchscreen using Kelpy, the Kid Experimental Library in Python, which is available under the GNU Public License (Piantadosi, 2012). Spoken sentences used in the experiment were recorded by an adult female in a soundproof booth.

Procedure

The study contained four blocks, each with a training and testing phase. The toy objects were presented during the training phase, along with their lexical labels. Productive taps (toy object in *choice*, button in *no-choice*) elicited a sentence containing the label for the object at the end. Once tapped, the toy-to-be-labeled expanded in size to draw the participants attention to the correct referrent (see Figure 2). Each time a toy object was tapped, a sentence—from Sentences 1-3 (see Table 1)—labeled the toy until it had been tapped 6 times in total. After the sixth tap and labeling sentence, the toy changed to grayscale to indicate that it could not be tapped or presented again (as shown for the “kogay” in the bottom two panels of Figure 2). The training phase ended when all toy objects on the screen had been tapped/labeled 6 times in total and were all grayscale.

Figure 1: Stimuli paired with their novel names.

Table 1: Sentences recorded for the experiment.

	Training sentences
(1)	”Look it’s a ________ .”
(2)	”Look at the ________ .”
(3)	”Say hello to the ________ .”
	Memory test prompt
(4)	”Can you find the ________ ?”

The testing phase followed the training phase. All 15 toys were presented on the screen at once. Children were asked to find each toy that was presented during the training phase after the appropriate verbal prompt (e.g., “Can you find the *kogay*?”, sentence 4 in Table 1). The locations and presentation order of the 15 toys were randomized across trials and participants. After a guess was made, the next verbal prompt would be asked. No feedback was given to the participant after a guess was entered; there were no changes in the appearance or behavior of toys during this phase. It is important to note here that chance performance on this task was thus very low; if children touched toys randomly during the test phase, their accuracy would be 1/15.

The experiment was structured so that each successive block raised the difficulty by increasing the number of toys

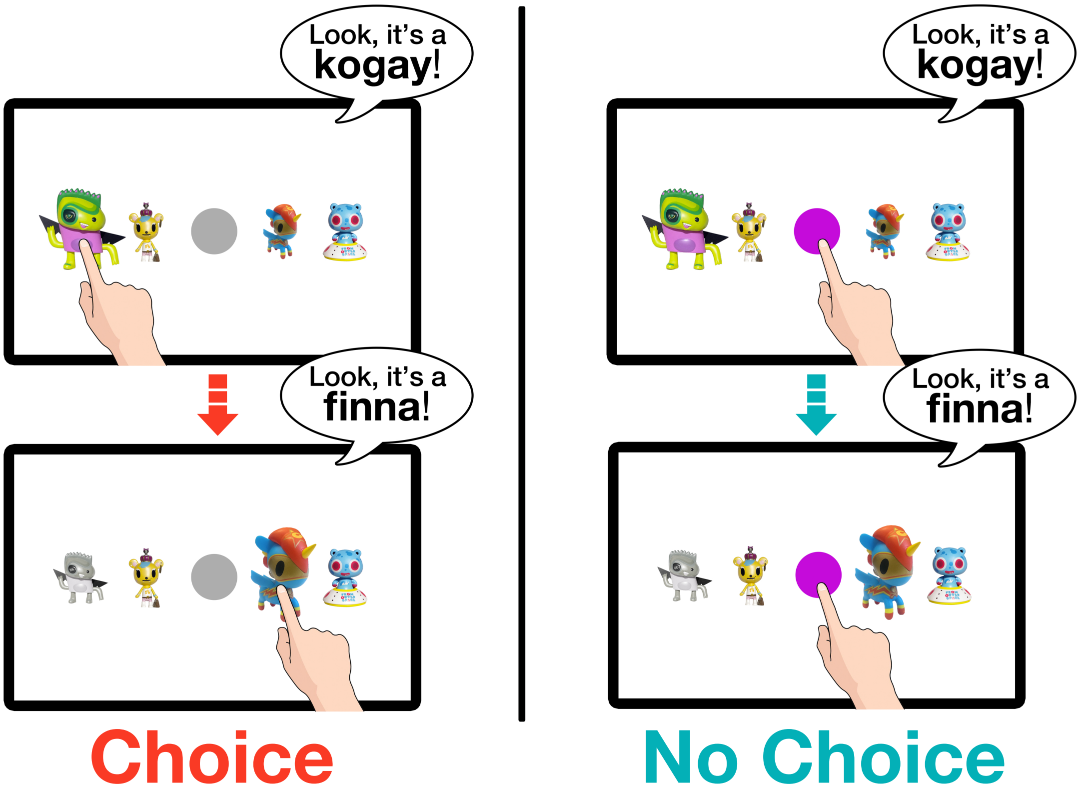

Figure 2: Example displays for 4-object training block for the *choice* condition (left) and the *no-choice* condition (right).

presented. The first training block presented a single toy, followed by training blocks with 2, 4, and 8 toys, respectively. The toys that were presented to children across the training blocks were always different, such that each toy was trained and tested in only one block, with no repetitions. Figure 2 includes examples of training screens for the 4-toy block in both the *choice* and *no-choice* conditions. All children progressed through all blocks, regardless of their performance on previous blocks. This design—with blocks of increasing difficulty—ensured that participants would not perform at ceiling in order to give us the best possible chance of observing an effect due to condition.

Analysis

The primary analysis investigated the effect of self-direction on learning outcomes. We hypothesized that self-direction would have a positive impact on learning, and that children in the *choice* condition would be more accurate in the toy-identification task than children in the *no-choice* condition. To assess the effect of self-direction, we ran a generalized linear mixed effects regression predicting accuracy as a function of condition (*choice*, *no choice*), block (1-, 2-, 4-, or 8-toy, treated ordinally), age (scaled), interaction between condition and block, and random intercepts by subject. Our primary focus and expectation was a condition effect, with accuracy significantly predicted by condition. Secondary expectations included a block effect (accuracy decreasing as blocks per toy increased), an age effect (accuracy increasing for older children), and possibly an effect for the interaction between condition and block.

A second analysis tested whether children across the two conditions demonstrated different degrees of engagement with the task as a function of the condition type (*choice* or *no choice*. If self-direction causes learners to more readily engage with learning material—as previous studies based on subjective reports by educators and students have suggested—we would expect children to be more engaged during the *choice* condition than the *no-choice* condition. We chose response times as an objective measure of task engagement. We recorded children's response time to each question during the testing phase, starting from the onset of the target word (e.g., the beginning of the "k" sound in "kogay" in the memory-task question "Can you find the kogay?"). We chose this point because it was the earliest moment at which children could potentially identify the target toy. We hypothesized that participants would be more engaged during self-directed learning, and would thus exhibit faster response times in the *choice* condition due to increased interest and attention to the task.

Outliers were removed from the data before it was entered into the two analyses described above. Response-time outliers were defined as 2.5 standard deviations above the mean (M=6.33 s, SD=13.35 s); thus, all trials with a time greater

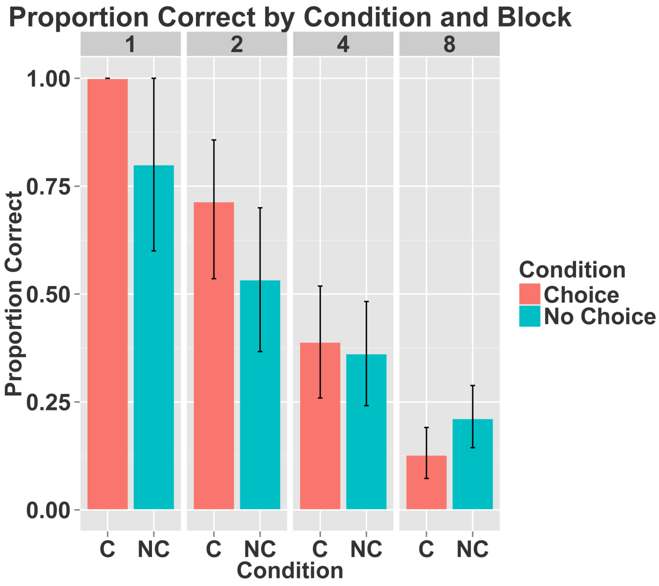

Figure 3: Accuracy on testing phase by block and condition (*choice*, *no choice*).

than 39.69 s were excluded from further analysis (N=7, adjusted M=5.04 s, adjusted SD=4.18 s). The discarded outliers were scattered across children and appeared approximately equally distributed across the *choice* and *no-choice* conditions.

Results

Accuracy

Testing phase accuracies per block and between conditions are shown in Figure 3. Accuracy trends across condition show that children perform better in the *choice* condition than the *no-choice* condition on earlier blocks, but that there is no difference on the later, more difficult testing blocks. Accuracy also decreases overall as the blocks progress and become more difficult, as expected.

Table 2: Generalized linear mixed model results.

Factor	Coef.	SE	z	p
Intercept	4.55	0.80	5.69	<1.3e-08 ***
NoChoice	-2.52	0.98	-2.58	<0.01 **
Block	-1.67	0.24	-6.88	<6.0e-12 ***
Age(scaled)	0.04	0.16	0.26	0.79
NoChoice:Block	0.80	0.29	2.74	<0.006 **

Table 2 details the results of the mixed-effect model. Children performed significantly worse in the *no-choice* condition as compared to the *choice* condition (β=-2.52, z=-2.58, p<0.01). Children also performed worse on later blocks—which required remembering more word-object pairings—than on earlier blocks (β=-1.67, z=-6.88, p<0.0001)[1]. Finally, there was a significant interaction between the *no-choice* condition and block (β=0.80, z=2.74, p<0.006). This significant interaction indicates that the improved performance of the *choice* condition over the *no-choice* condition wanes in later blocks, when the memory task is made more difficult by increased numbers of objects and children progress further into the testing session. Age was not a significant predictor of performance in our sample of child participants (β=0.04, z=0.26, p=0.79).

These results support the hypothesis that self-direction facilitates learning, as children in the *choice* condition exhibited better overall learning than those in the *no-choice* condition. However, as Figure 3 shows, this effect is driven by the early blocks with fewer objects. This suggests that the effect either only appears early in learning or for small numbers of objects, which are indistinguishable given the current experimental design.

Importantly, the fact that children perform better in the *choice* than the *no-choice* condition suggests that the boost in performance is likely related to differences in engagement across the two conditions. In the single-object test block—in which children were only learning the name for a single toy object—the children did not differ in terms of the order in which the information was selected. In both conditions, children only heard the name of the single object on the screen. The only factor that differed in this testing block was whether children touched the object itself to hear its label (*choice* condition) or whether they touched a button to hear the object's label (*no-choice* condition). It is somewhat surprising, then, that this subtle difference detectably impacted children's performance in this block.

To further investigate the potential difference in engagement across the conditions (as evident from the difference in the first testing block), response times were analyzed.

Response times

Though the difference across conditions in the single-object block suggests that children were differentially engaged with the learning material, this difference had no detectable impact on children's reaction times across the two conditions. Children made selections at approximately the same speed across the *choice* condition (M=4.10 s) and the *no-choice* condition (M=4.07 s). These means were not significantly different from each other, according to a Wilcoxon signed-rank test (W=22297, p=0.65).

Though differences in engagement did not appear in reaction times, reaction time is just one of many ways differences in engagement could be manifested. Other independent measures (e.g., visual fixation, physiological changes) may be needed to test our interpretation of engagement as the most likely mechanism underlying observed differences in performance across conditions.

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[1] Block was ordinally ranked in this analysis, but we note that numerically ranking instead does not change the pattern of results that we report here.

Conclusion and Discussion

These results provide evidence that self-directed learning can enhance short-term memory retention for novel object-word pairings in children. The main effect of condition indicated that self-direction positively affected accuracy on the memory task across conditions, though this effect was moderated by block and, correspondingly, task difficulty. In the final block—the one that required children to track and remember the most object-word pairings—children performed near floor across both conditions. The observed difference across conditions in the single-object block interestingly suggests the boost in performance from self-selection is likely due to differential degrees of engagement across conditions—not the ability to select the order of incoming information.

A key aspect of this work is that it demonstrated the benefits of self-directed learning in children in a controlled context. Much of the previous research with children has taken place in educational settings in which self-direction was confounded with other variables, such as the modality of information presentation. Our study carefully controlled for as many extraneous variables as possible—including the modality, content, and duration of the learning material—across the *choice* and *no-choice* conditions. Both groups of children saw and heard exactly the same materials, exactly the same amount of time, but only the *choice* group had the ability to select the information to be presented directly.

Further work will be required to determine how self-direction interacts with other factors known to impact learning, such as task difficulty. These findings are in line with previous work that has reported better learning in self-directed conditions with adults (e.g., Markant, DuBrow, Davachi, & Gureckis, 2014). Broadly, these results demonstrate that the ability to select information enhances learning for young children, likely due to the increased engagement associated with self-direction itself.

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