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The Effects of Interactive Screen Media and Desirable Difficulty on Word Learning in Young Children

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Abstract

Screen media usage has greatly increased in recent years, even for children. Screen media can be very useful, and has been shown to be an effective tool for learning in children older than two years of age (Kirkorian, Wartella, & Anderson, 2008). However, children under the age of two experience what is called the video deficit effect; that is, they do not learn from screen media (Linebarger & Vaala, 2010). The majority of past research looking at the video deficit effect has focused on viewing videos as screen media. Yet, as technologies have advanced more and more children have gained access to increased amounts of interactive screen media. This study aims to look at learning with interactive screen media through a word-learning iPad application. The application utilizes the idea of desirable difficulty, the theory that there is a certain level of difficulty at which learning is enhanced, to maximize word learning by examining the role of semantic similarity and previous knowledge when selecting words for learning by the application. This study finds that the video deficit holds true even for interactive screen media. Furthermore, desirable difficulty design within the application does not impact performance on testing. These results indicate that a word-learning application, even an interactive one, may not be the best platform for increasing young children’s vocabularies.
The Effects of Interactive Screen Media and Desirable Difficulty on Word Learning in Young Children

The use of mobile devices is rapidly becoming ubiquitous as these technologies advance. This is especially true for usage among children. In a recent review by Common Sense Media (Fall 2013), it was found that 72% of children aged 0-8 had ever used a mobile device for some type of media activity, up from 38% in 2011. This increase is seen in even the youngest children as it was found that 38% of children under the age of two had ever used a smartphone, tablet, or similar device for playing games, watching videos, or engaging in related activities. This is up from 10% in 2011. Because there has been such a dramatic increase in screen media usage for children, it is important to understand how media usage affects learning.

Screen Media

It has been repeatedly shown that children older than two years are able to learn from screen media (Kirkorian, Wartella, & Anderson, 2008; Rice, Huston, Truglio, & Wright 1990; Linebarger & Vaala, 2010; Rice & Woodsmall, 1988). However, for children under the age of two learning from screen media is not nearly as robust (Kirkorian et al, 2008; Krcmar, Grela, & Lin, 2007; Barr & Hayne, 1999; Troseth & Deloache, 1998; Schmitt & Anderson, 2002; Linebarger & Vaala, 2010; Linebarger & Walker, 2005; Krcmar, 2010; Deloache & Chiong, 2009; Zimmerman, Christakis, & Meltzoff, 2007). This phenomenon is known as the video deficit effect, and the current American Academy of Pediatrics recommends to avoid screen media usage for children under the age of two (American Academy of Pediatrics, 2015). However, some work has found that co-viewing and caregiver-child interaction during viewing of screen media can help to lessen the video deficit (Kirkorian et al, 2008; Fidler, Zack, & Barr, 2010; Linebarger & Vaala, 2010; Deloache & Chiong, 2009).
Most of this previous work on screen media has focused on viewing videos. However, with new technologies, there has been an increase in usage of more interactive screen media, that is, screen media that asks the user to interact with the technology rather than just passively view it. Knowing that interaction can help to mediate the video deficit, it is useful to examine the effects of interactive screen media in learning. The work that has been done so far in this area is limited in scope. In a study with adults, it was found that people were better able learn how to tie knots from an interactive video than from an un-interactive video (Schwan & Riempp, 2004). This study, however, did not look to see if learning from these videos was different than learning from instruction in person. In a study by Ricci & Beal (2002), six and seven year old children in a media-based interactive storybook condition recalled and comprehended the story better than children who just heard a narration of the story. However, the interactive story did not differ from the un-interactive video of the story. Interactive touch-screens were examined in a study in which 15 month olds were shown either an experimenter pushing a virtual button on a screen or an experimenter pushing an actual button. The infants were then asked to either push a virtual button or a real button. Infants were more successful when asked to push the same type of button as the experimenter than when asked to push the other type of button (Zack, Barr, Gerhardstein, Dickerson & Meltzoff, 2009). This may suggest that young children are unable to generalize learning from screen media to the tangible world and vice versa, even when that screen media is interactive. The current research on the effect of interactive screen media on children’s learning does not offer clear conclusions.

Desirable Difficulty

When looking at learning, it is often assumed that conditions that enhance performance during training or instruction are conditions that enhance learning in general. However, this is
not always the case. Conditions that increase the rate of acquisition during training can lessen one’s ability to recall and generalize that information in the long run, while conditions that are more difficult and slow the rate of acquisition initially can increase the ability to later recall and generalize that information (Bjork & Bjork, 2011). These conditions that are more difficult initially but lead to enhanced learning later on are referred to as desirable difficulties.

This idea was first investigated by Davis, Sutherland & Judd (1961) with adults. Participants were asked to either recognize a set of 15 two-letter syllables or 15 two-digit numbers out of either a list of 30, 60, or 90 syllables or numbers, or to recall a set of syllables or numbers out of 90 options. They found that participants’ recognition performance was no better than their recall performance when both were out of 90 options. Furthermore, recognition performance increased as the number of options increased even though recognition took longer as the number of options increased. This supports the idea that tasks that are initially difficult can lead to more robust learning.

Desirable difficulty has been examined in children in the scope of interleaving and blocking items (Bjork & Bjork, 2011; Kornell & Bjork, 2008), spacing training (Vlach & Sandhofer, 2012; Vlach, Sandhofer & Bjork, 2014), varying conditions of learning (Smith, Glenberg, & Bjork, 1978; Kerr & Booth, 1978), and testing as a method of studying (Landauer & Bjork, 1978). Interleaving, presenting materials mixed together rather than in their own blocks, has specifically been examined within the context of word learning. Results suggest that interleaved items are more difficult to initially learn but are better learned in the long run. In a study by Schneider, Healy, & Bourne (2002), the effects of interleaving on the learning of English-French vocabulary were investigated. The vocabulary items were either blocked by category (ex. vehicles, body parts) or interleaved together. The translation direction was also
varied for the words so for some conditions French needed to be translated to English and in others English needed to be translated to French. At immediate testing the harder conditions (interleaved and French-English translation) showed reduced performance as compared to the easier conditions. However, at delayed testing the harder conditions showed increased performance as compared to the easier conditions. This demonstrates increased learning with increased difficulty early on.

**Present Study**

The present study aims to investigate the effect of interactive screen media and desirable difficulty on young children’s word-learning. A word learning application will be used to investigate the effectiveness of toddler word learning from interactive screen media. Based on previous literature about interactions with others during screen media usage, we expect that children will learn from the app. The app will also examine the effect of desirable difficulty on word learning in toddlers. It will do so by pairing target words with distractors on two dimensions. First we consider semantic relationships that are either near or far. The second pairing involves the use of distractors that are either reported as produced by the children or not. For example, for the target word “cat”, a near distractor might be “dog” and a far distractor might be “apple”. “Dog” could also be reported as produced if a child’s caregiver reports that they produce it on their own. Alternatively, if “apple” was not reported by a caregiver as produced by the child it would be a distractor that was not reported as produced. Following the theory behind the effect of interleaving, we believe that distractors that are unknown and near in semantic relation will require the child to have to discriminate more between the two words making those conditions more difficult. Similar to the Schneider et al (2002) study, we predict that children will have better performance during training for easier conditions than for harder
conditions. For this study an easier condition is considered to consist of target words paired with semantically far and reported produced distractors (Far/Known distractors) and a harder condition is considered to consist of target words paired with semantically near and not reported produced distractors (Near/Unknown distractors). In testing, we expect to see the opposite performance, as evaluated by accuracy on a perceptive vocabulary test, that is, performance should be better for harder conditions than easier conditions.

In order to examine these questions, 20 two-year old participants came in for two visits, one week apart. At each visit there were two phases: a training phase where the children were trained on target words paired with distractors from different difficulty conditions, and a testing phase where children were tested on these with a perceptive vocabulary testing measure using picture cards. Accuracy of identification of target words was assessed during training, testing, and a delayed test to determine how interactive screen media and difficulty level affected word-learning.

**Methods**

**Participants**

Twenty-nine participants, 13 females and 16 males, ranging in age from 24 months to 26.9 months (M=25.155, SD=.888), were recruited from a participant database. This database was created from information voluntarily provided by parents about their children. All children recruited from the database live in the Boulder, Colorado metropolitan area. Nine participants were not included in analysis: five due to technical difficulties; four because the children did not complete the full two visits. The final participant group used for analysis included 20 participants, 8 females and 12 males, ranging in age from 24 months-26.9 months (M=25.195,
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SD=.865). At the end of each visit parents were compensated five dollars for travel and the children received a picture book for their participation.

Materials

Macarthur-Bates Communicative Development Inventory-III (MCDI). The MCDI is a well-tested inventory for assessing language knowledge in children up to 30-months-old (Dale & Fenson, 1996). All the words trained in the app are concrete nouns from the inventory. Six pictures of each word were included in the experiment and chosen through google image searches. Each picture was unique, had a white background, and was judged to be a prototypical example of the word by an adult. Four of the pictures were used in the app. for training, and the remaining two pictures of each word were used to make picture cards for the testing phase (See Appendix A for example pictures of a target word.).

Word-Training Application. A word-training app was developed for the training phase of the experiment. The app displays a target word and its paired distractor and asks the child to touch the target word, using phrases such as “Touch the [target word]” and “Where is [target word]?” (Figure 1). If the child answers correctly, they are reinforced with praise, in the form of encouraging phrases such as “Good job!” and “Way to go!”, by the app. If the child answers incorrectly, the picture of the target word fills the whole screen and they are asked to select it again. When the child touches the correct answer they are reinforced with praise. The child always receives praise regardless of if they were correct or not on their first attempt. For analysis, children receive a correct score for touching the target word when asked the first time, and an incorrect score when they touch the distractor when asked the first time, even if they touch the target word afterwards. Each target word and distractor can be presented four times for
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A total of 64 trials. A different picture of each target word and distractor is displayed each time they are presented. A variety of female voices were used to give instructions and to offer praise.

![Figure 1](image.png)

*Figure 1.* The app displays a target word and its distractor then asks the child to touch the target word. If a child selects the wrong word, the correct word fills the screen and the child is asked to touch the word again.

**Picture Card Task.** A picture card task was used during the testing phase of the experiment as a way to measure comprehension of target and control words. During the picture card task, a picture card of each target and control word is presented with two distractors. The distractors used are selected so that they satisfy two criterions: they do not match the distractors used in the app and they are not too difficult to discern from the target word. Aside from those two criterions, distractor selection has no other constraints. The position of the target word among the distractors is randomized. The pictures of the target words are different than the pictures trained on in the app. After the child is presented with picture cards of the target word and distractors, the child is then asked to select the target word. For example, for the target word “ant”, a picture card of an ant would be shown with two other randomly selected picture cards from the set of concrete nouns from the MCDI that were not part of the vocabulary used on the app. The child would be asked to find the ant. No feedback is given as to whether the child is correct or not but the child is thanked for making a choice to encourage engagement. Answers are scored as correct if the child correctly identified the target word and incorrect if they selected
a different word. Children are not given feedback on whether they answer correctly or incorrectly.

**Procedure**

Participants came in for two 45-minute visits approximately one week apart.

**Prior to First Visit.** Before the first visit parents fill out the MCDI. The MCDI results are used to indicate which words on the app and picture cards are reported as produced, and thus likely to be known, by the child. It is important to note that words reported as produced on the MCDI are considered to be known by the child, and words not reported as produced are considered to be unknown to the child in this study. That information is then used to select target, distractor, and control words for each child that respect the difficulty variants of our experimental design. Two lists of words are created for each child so that children were trained on 32 target words over two visits. The words are split across two visits to keep the amount of words trained on at each visit manageable for the child and to provide an opportunity for delayed testing at the second visit. The list trained on during the first visit is referred to as List 1, and the list trained on during the second visit is referred to as List 2. Each list contains 16 target words, 16 distractors, and 4 control words. Target words are words that are not reported produced by the children that will be trained and tested on. Distractors are words that the child is not tested on and may know or not know at the start of the study. Distractors are selected to span four categories with four words each: Near/ Known, Near/ Unknown, Far/ Known, and Far/ Unknown. Near/ Known distractors are words that are semantically near to their paired target word and are reported produced. Near/ Unknown distractors are words that are semantically near to their paired target word and are not reported produced. Far/ Known distractors are words that are
semantically far from their paired target words and are reported produced. Far/Unknown distractors are words that are semantically far from their paired target words and are not reported produced. Control words are words that are not reported as produced and are not trained on but are tested on.

**First Visit.** On the first visit, children were trained on List 1 target words with the app. Children were encouraged to get through at least two blocks of the app. training, and spent about 10-15 minutes on training. The children completed 2.4 blocks in the app on average so that each target word was presented at least twice. Following training, children were tested on List 1 target and control words with the Picture Card Task. Caregivers also filled out a survey about their screen media usage.

**Second Visit.** On the second visit, approximately one week later, children trained on a second list with the app. Children completed 2.35 blocks in the app. on average which is consistent with training at the first visit. Following training, children were tested on List 2 target and control words with Picture Card Task. They were then tested on List 1 target and control words for a second time, as a delayed test, with the Picture Card Task in order to assess retention of target words. For a subset of participants (N=10), caregivers also filled out a shortened MCDI consisting of only List 2 words.

**Results**

It was found that in some lists of words, target-distractor pairs were ambiguous. That is, they were impossible to tell apart using our metric of assessment. For example, if cloud and sky were paired together or shoe and sneaker, a child would not be able to tell those apart as the pictures would have been too similar to separate or could have reasonably been assumed to
pictures of the same thing. Also, for some children target words were repeated across visits as the app could not generate two distinct lists of words based on the child’s vocabulary. Ambiguous pairs and repeated words were not counted in analysis.

**Training**

**List 1.** Children’s performance, as determined by the proportion of correct responses during training in the app, was influenced by whether distractors were semantically near or far, but not by whether distractors were or were not reported as produced (Figure 2). Children had significantly higher accuracy for target words paired with semantically far distractors (F(1,19)=5.135, p<.05). However, there was no significant difference in accuracy for target words paired with distractors either reported as produced or not reported as produced (F(1,19)=.220, p>.05). Additionally, there is no significant interaction between semantic nearness and whether the word was produced. During the training period, children were more often able to identify target words with semantically far distractors than near distractors, but correctly identified target words with known and unknown distractors at the same rate.

![List 1 Training Accuracy by Distractor Type](image)

*Figure 2.* Children performed better on target words paired with semantically far distractors. Reported production did not influence performance.
**List 2.** Similar results were found for List 2 training (Figure 3). Children again had higher accuracy for target words paired with semantically far distractors ($F(1,19)=12.696$, $p<.05$), but there was not a significant difference in accuracy for target words paired with distractors either reported as produced or not reported as produced ($F(1,19)=.265$, $p>.05$). An interaction was not found between semantic nearness and reported production of distractors ($F(1,19)=.222$, $p>.05$). Again, children showed differences in training performance for semantic relation of distractors but not reported production.

**Immediate Testing**

**List 1.** There were no significant differences in accuracy, as determined by the proportion of correct responses in the picture card task, for target words paired with semantically near or far distractors ($F(1,19)=2.676$, $p>.05$) or target words paired with distractors reported as produced or not reported as produced ($F(1,19)=.459$, $p>.05$) (Figure 4). An interaction was not found between semantic nearness and reported production of distractors ($F(1,19)=.017$, $p>.05$).
A marginally significant effect of condition was found \((F(4,76)=2.446, p=.054)\) (Figure 5). Condition is defined by what distractors the target words were paired with: Near/Known, Near/Unknown, Far/Known, Far/Unknown, and no distractors for control. Post-hoc tests reveal that children had higher accuracy for target words paired with Far/Known distractors than control words \((t(19)=-2.343, p<.05)\) as well as higher accuracy for target words paired with Far/Unknown distractors than control words \((t(19)=-2.678, p<.05)\). In immediate testing, children correctly identified target words at the same rate regardless of difficulty; however, they were more often able to identify target words in the Far/Known and Far/Unknown conditions more often than in the control condition with marginal significance.

![List 1 Immediate Testing Accuracy by Distractor Type](image)

*Figure 4. Performance was not influenced by either semantic relation or reported production of distractors.*

![List 1 Immediate Testing Accuracy by Condition](image)

*Figure 5. Children performed better in the Far/Known and Far/Unknown conditions than the control condition.*
**List 2.** There were no significant differences in accuracy for target words paired with semantically near or far distractors ($F(1,19)=.121, p>.05$) or target words paired with distractors reported as produced or not reported as produced ($F(1,19)=.019, p>.05$) (Figure 6). An interaction was not found between semantic nearness and reported production of distractors ($F(1,19)=.024, p>.05$). Unlike List 1, no effect was found for condition ($F(4,79)=.415, p>.05$) (Figure 7). List 2 immediate testing again showed that semantic nearness and reported production of distractors did not influence learning of the target words.

**Figure 6.** Performance was not influenced by either semantic relation or reported production of distractors.

**List 2 Immediate Testing Accuracy by Condition**

*Figure 7. Children’s performance did not differ across conditions.*

**Delayed Testing**
List 1. Similar results to immediate testing are seen in delayed testing (Figure 8 and Figure 9). Children’s accuracy did not differ for target words paired with semantically near or far distractors (F(1,19)=.184, p>.05) or for target words paired with distractors reported as produced or not (F(1,19)=1.445, p>.05). There was not a significant interaction between semantic nearness and reported production of distractors (F(1,19)=.761, p>.05). Accuracy did not differ across conditions (F(4,79)=.968, p>.05). By the time of delayed testing, the learning differences seen in immediate testing diminishes.

![List 1 Immediate Testing Accuracy by Distractor Type](image1)

*Figure 8.* Performance was not influenced by either semantic relation or reported production of distractors.

![List 2 Delayed Testing Accuracy by Condition](image2)

*Figure 9.* Children’s performance did not differ across conditions.
Discussion

This study aims to answer two questions, the first of which being whether young children can learn from interactive screen media. Here we found evidence that the target conditions did not outperform the control condition in nearly all cases (with the exception of the far conditions in List 1 immediate testing). This suggests that children may not be able to effectively learn from the app at least with the limited exposure of this experimental protocol. This is not surprising when we consider previous screen media research related to two-year olds. Though it has been found that two-year olds can in some cases learn from screen media, there is a fair amount of work indicating that they still have trouble learning and retaining information presented only through screen media (Hayne, Herbert, and Simcock, 2003; Troseth & Deloache, 1998; Schmitt & Anderson, 2002). It may be that the children in this study were too young to truly benefit from screen media. It is also possible that they need more time to interact with the app to learn. This is supported by Troseth (2003) who found that practice was key to learning from static screen media presentations. The children in this study spent a limited amount of time on the app and may not have had enough time to become proficient learners using the app. Caregivers did fill out a survey on screen media usage for their children, and in the future we may use the data from the surveys to guide the experimental protocol and analysis. It is an interesting question to explore whether two-year olds with more screen media exposure performed better or worse than their peers. In future work, it would also be useful to examine the effects of interactive screen media on learning with the interaction of age and practice.

This second research question this study aimed to look at was the effect of desirable difficulty on word learning. As predicted, children performed better during training in the condition where items are further apart in semantic space. This is commonly found as the easier
type of semantic relationship to learn and our results suggest this is true for children learning from screen media, at least initially. However, this effect did not continue into either immediate or delayed testing performance. This could be due to the difficulty of the task or the inability of young children to learn through our screen media app. Interestingly, children did have better performance in both far conditions than the control condition for List 1 immediate testing suggesting that they were able to learn something from the app. This may suggest that there is a weak effect of semantic similarity in testing. The sample size for this study was small (N=20), and this effect might be amplified with a larger sample. The effect of difficulty may also be lost by testing as a result of children’s natural word learning trajectories. Children learn words at a rapid pace at this age which may overshadow any effects of desirable difficulty in this context, especially by the second visit. For a subset of participants (N=10), caregivers did fill out a shortened MCDI consisting of List 2 words. The data from the checklists was not analyzed in this study; however, it could be useful to look at effects of desirable difficulty after learned words are controlled for. In future experiments, it may be important to utilize measures of word learning throughout the project to control for natural word learning.

While there was some effect for semantic similarity, whether or not distractors were reported as produced had no effect in either training or testing. It is important to note that words reported as produced on the MCDI are considered to be known by the child, and words not reported as produced are considered to be unknown to the child in this study. It is thought that distractors that are unknown to the child will be harder to discern from target words and will create a desirable level of difficulty that may enhance learning and retention. However, as it is possible to comprehend words without producing them, the unknown distractors in the study may have been comprehended by the children and potentially be known by the children as well
as the known distractors. In future work it may be important to re-examine our measure of knowing a word and the effect of knowledge on learning with a measure of vocabulary comprehension rather than production.

Conclusion

This study adds support of the video deficit effect in young children, even when children are using interactive screen media. Furthermore, it shows that our definition of desirable difficulty did not facilitate learning within the context of the app. We should note that results were trending towards a possible effect of semantic similarity on learning and the idea warrants further exploration. Further experimental and theoretical work is needed to develop clear conclusions about the effect of desirable difficulty in this context of early language learning, especially in regards to screen media.

This is especially important as the usage of screen media continues to increase. As screen media is used often and often for learning, it is essential that we understand both how children learn with screen media and how difficulty of items to be learned affects the ability to learn and remember words.
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Appendix A

Pictures for Target Word “Jacket”