THE EFFECTS OF DIFFERENT TYPES OF MEDIA PRESENTATION ON CHILDREN’S SPATIAL MEMORY

by

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ABSTRACT

Dual representation is the notion that photographs must be interpreted in two ways for full understanding. First, one must recognize that the photograph is an object itself. Second, one must recognize that the photograph is a symbolic representation of a scene as it exists elsewhere in the world. The purpose of this research is to investigate whether preschoolers aged 4-5 years are able to understand images presented on tablets the same way that they understand images presented on physical cards. Experiment 1 compared children’s memory for physical photographs and digital photographs, finding significant differences between the two. The experiment replicated previous work finding boundary extension in the card condition, but not in the tablet condition. Experiment 2 followed Experiment 1 to determine whether the proximity of edges in the digital photograph condition, rather than the digital nature of the photographs themselves, caused the discrepancy between conditions in Experiment 1. When physical photographs were placed on top of a blank tablet, results replicated the card condition from Experiment 1. Experiment 3 encouraged children to conceptualize digital photographs in the same way as physical images by using a “magic trick” to make them interpret digital images on-screen as being real, physical cards that were magically transported to the screen. With this intervention, preschoolers did demonstrate boundary extension for digitally-presented images. In all experiments, the asymmetry in choices was not due to a selection bias, as tested with a guessing game task. We propose that the touchscreen tablet presentation of photographs interferes with young children’s ability to understand these images as symbolic referents. This raises concerns regarding the use of educational technology for teaching symbolic concepts.
Chapter 1

INTRODUCTION

Consider a postcard with a photograph of the Eiffel Tower on it. When viewing this photograph, you understand that the postcard is not only an object with a picture of the Eiffel Tower on it, but also serves as a representation of the real Eiffel Tower as it exists in Paris. This dual understanding of pictures is referred to as “dual representation”. Dual representation suggests that an image can be interpreted as an object in and of itself, but also as a representation of something that exists elsewhere in the world (Sheehan & Uttal, 2016). It is important to determine when children develop the ability to understand dual representation, as it holds implications for learning. In a review of relevant literature, Sheehan and Uttal (2016) state that touchscreens may affect children’s conceptualization due to their entertainment value—obstructing children from focusing on symbolic referents—but that it is also possible that touchscreens can help children focus on relevant symbols. These researchers ultimately conclude that more research regarding the effectiveness of the educational use of touchscreens for children is necessary (Sheehan & Uttal, 2016).

In the current research, we study this question in a new way—by testing for the presence of a phenomenon called boundary extension in 4-5 year-old children. In healthy adults, boundary extension is a memory illusion in which adults falsely remember having seen a wider angle view of a photograph scene than was actually presented (Intraub, 2010). Research has been conducted on the presence of boundary extension in young children, but we will use both digital and physical photographs to
determine whether children perform differently dependent upon the medium of photograph presentation. We will carry out three experiments to explore the presence of boundary extension when photographs are presented digitally as compared to physically in order to investigate whether touchscreen presentation interferes with children’s spatial cognition processes. First, relevant research regarding dual representation will be reviewed. Next, we will discuss the topic of boundary extension. Finally, current research and findings regarding young children’s demonstration of boundary extension will be presented.

**Dual Representation**

Dual representation is the understanding of a photograph as both a physical object itself, but also a representation of a scene that exists in elsewhere in the world (Sheehan & Uttal, 2016). This interpretation requires an understanding of the symbol itself, as well as the entity that the symbol refers to (DeLoache, 2000). There are essentially two natures to symbolic objects—the literal nature, as well as the representative nature.

While most adults understand the concept of dual representation, this understanding takes time to develop in young children. Dual representation is an important concept for young children to understand, as symbolic representations are pervasive in our world. Educators and parents often implement learning tools that involve screens and touchscreens, and the use of these devices for education relies upon the assumption that children are able to understand the symbolic nature of photographs presented on touchscreens (Newcombe & Frick, 2010). In order for children to develop symbolic understanding, they must develop an understanding of dual representation. Children must acquire the ability to connect entities on screens to
real-world referents, and researchers state that more research is necessary in order to
determine whether touchscreens aid or hinder children in understanding symbolic
entities. (Sheehan & Uttal, 2016). While some research supports the use of
touchscreen tablets for young children’s learning, other research raises some concern.

Sheehan and Uttal (2016) comment on relevant literature claiming concerns
regarding young children’s abilities to understand the symbolic nature of entities
presented on touchscreens. Some research supports the use of interactive screens as an
aid in understanding on-screen referents. Choi and Kirkorian (2016), find that 2 year-
old children are able to transfer learning from an interactive screen to a physical
apparatus (as cited in Sheehan & Uttal, 2016). However, Sheehan & Uttal also
comment that there is concern that this interactivity leads children to understand the
images presented on the screen as objects themselves, and not as symbols that refer to
entities in the real-world. Children may focus on the screen itself, rather than
perceiving the image presented as representing a scene that exists elsewhere. (Sheehan
& Uttal, 2016).

Some research suggests that the interactivity of screens may help children
better understand the picture’s referents and better navigate dual representation.
Lauricella, Pempek, Barr, and Calvert (2010) created a hide-and-seek task for children
aged 30 months and 36 months. Participants either directly viewed an adult hiding a
toy, watched an adult hide a toy on a screen, or played an interactive computer game
which demonstrated where the toy was hidden. Children in the interactive game
condition performed as well as children who directly observed an adult hiding a toy,
while children in the screen condition did not perform well when locating the toy. This
research indicates that children’s learning from screens may depend upon the
interactivity associated with the screen (Lauricella et al., 2010). However, other research indicates that learning from screens inhibits children’s ability to understand the representative nature of what is presented.

Schmitt and Anderson (2002) found that 24 month-olds were able to find a hidden toy when made to believe they were watching the toy being hidden in real life. However, these children struggled to find the toy when watching the toy being hidden via a screen, indicating a failure to relate what is shown on screens to their real-life referents (Schmitt & Anderson, 2002). Further, Flavell, Flavell, Green, and Korfmacher (1990) investigated whether young children think of television (TV) images as real objects. In this experiment, 3 and 4 year-old children were shown videotapes of both static and dynamic images. Children were asked questions about whether the experimenter would be able to touch the object in the image if the top of the TV was removed (allowing an arm to reach inside the TV), whether the object would fall out if the TV was tipped upside down, and whether the image was a real object or a picture of an object. Results showed that for 3 year-olds, performance did not exceed chance. However, 4 year-olds more consistently demonstrated belief that the images on the screen were mere pictures of objects and not objects themselves (Flavell et al., 1990).

These researchers conducted follow-up experiments to better-understand these results. Children were presented with real objects, physical photographs of objects, and digital images of objects presented on screens. They were asked similar questions as described above. Results indicate that 4 year-old children understood images on screens as representing an object not physically present—objects that were unable to be held or manipulated. Three year-olds recognized screen images as actual objects,
rather than as a portrayal of the referent. These participants had difficulty understanding the screen image as not only an object itself, but also as a referent to something elsewhere in the world (Flavell et al., 1990).

This research may lead one to assume that young children aged 4-5 years are capable of acting like adults while using touchscreen technology. These children may have the ability to understand that these digitally-presented images are not mere objects but are also representations of scenes elsewhere in the world. However, Liben’s (2008) investigations regarding young children’s photograph literacy may suggest otherwise. Researchers asked young children to indicate whether two images were the same or different. In some cases, the scenes differed from photograph to photograph, while in other cases the scenes were identical with the exception that the photographs were taken from differing vantage points. If children stated that photographs were different, they were asked to determine whether the difference was due to “something that the photographer did or something that changed in the scene that had been photographed” (Liben, 2008).

Liben (2008) found that 3 year-old children were only successful in recognizing the difference between photographs taken closer or further away about 25% of the time, but that children were successful 50% of the time by 5 years. Further, 7 year-olds performed as well as most adults. Young children may have difficulty understanding change in vantage points when viewing photographs, and this difficulty suggests that young children may have difficulty looking at photographs not just as objects, but also as symbolic representations (Liben, 2008).

Newcombe & Frick (2010) explain why understanding symbolic representation in childhood is important for development and education. Spatial intelligence develops
over time, and is necessary in order to navigate the world. Spatial thinking assists in verbal thinking, and helps us reason in various domains. Importantly, spatial thinking directly applies to the science, technology, engineering, and mathematics (STEM) fields. If children are unable to understand the spatial concepts presented in digital photographs, they may have difficulty learning from educational tools which utilize touchscreens in order to teach the STEM disciplines (Newcombe & Frick, 2010).

We plan to test children who are older than children in previous research presented. We choose to focus on 4-5 year-old children, because Liben (2008) finds that at this age, children are becoming better at recognizing the differences in photographs of scenes taken from different viewpoints, but are still having difficulty understanding these differences. In order to test whether 4 to 5 year-old children understand the dual representation behind both physical and digital photographs, we will use what for adults is a very rapid, automatic process of scene construction. This process occurs when an adult understands an image as representing a place elsewhere in the world. We utilize boundary extension as a method to test the understanding of dual representation because boundary extension demonstrates an example of the dominance of the representative aspect of dual representation.

**Boundary Extension**

Boundary extension occurs when participants inaccurately remember having seen more of a scene than was actually presented in a stimulus photograph. When they see a close-up image of a scene and are asked to recall what they saw, adult participants often remember having seen a wider-angle view of that scene (Intraub, 2010). This occurs due to the automatic scene construction processes of our brains. Because we live in a surrounding world, but our visual system only allows us to take
in small snapshots of this world at any given time, our brain is constantly at work in order to integrate these snapshots in order to develop a cohesive view of space. Taken together, these processes work in a multisource model of scene construction, which is an underlying mechanism that results in boundary extension (Intraub, 2010).

Intraub (2010) explains how the multisource model for scene construction can lead to the boundary extension errors that adults make while recalling photographs of scenes. When mature adults view scenes, this scene triggers automatic processes and various sources of top-down information. Because our eyes are only capable of seeing small snapshots of the world at a time, our brain automatically anticipates how these small snapshots continue beyond our own view. The brain tries to “fill in gaps” so that we can better navigate and understand the surrounding world that we live in, even though we cannot physically see all of this world at once (Intraub, 2010).

According to Intraub (2010), the first stage of the multisource model is the generation or scene construction stage. We are embedded in a world in which we consistently have a sense of what is in our surroundings—above us, behind us, or below us, for example. Our brain uses this information to automatically place us within a spatial framework using various sources. First, visual information comes in as one source. Secondly, perceptual processes fill in missing information that the visual system failed to provide. The brain automatically predicts how a scene continues beyond the boundaries of visual information provided in order to place us in a spatial framework and to create one cohesive, surrounding view of the world. In this stage, we generate anticipatory representations of the world from a single viewpoint in order to understand our all-surrounding world (Intraub, 2010).
According to Intraub (2010), the second stage of the multisource model occurs when adults attempt to remember the scene that they viewed. In order to understand why boundary extension occurs when recalling the scene that was just mentally constructed, Intraub (2010) proposes that Johnson and Raye’s (1981) work on reality monitoring is applied here—during the second stage of the multisource model, adults often make a reality monitoring error. Because the brain’s automatically-generated amodal representations of the view beyond what was actually presented are so realistic, adults experience a reality-monitoring error. They think that they actually saw information that the brain mentally constructed as an anticipation of the continuation of the view. This anticipatory construction is so strong that adults are as sure that they actually saw this information as everything else that really was visually perceived, therefore falsely remembering having seen more of a view than was originally presented (Intraub, 2010).

While many studies report the occurrence of boundary extension in adult participants, less research has been conducted regarding the presence of this memory illusion in children. Quinn and Intraub (2007) sought to determine whether young infants, as young as 3-7 months, also exhibit boundary extension, as they also function within a continuous world. In a preferential looking experiment, these infants showed novelty preference for close-up scenes after having been presented close-up scenes. The infants’ novelty preference for close-up scenes following habituation to a close-up scene indicates boundary extension. These data indicate that infants believe they have already been shown the wide-angle view, when they were actually presented a close-angle view of the scene. (Quinn & Intraub, 2007).
Seamon, Schlegal, Hiester, Landau, and Blumenthal (2002) wondered whether children would also demonstrate boundary extension. Researchers questioned if children conceptualized photographs only as objects themselves, rather than as symbols also representing entities elsewhere in the world. If children only understood photographs as physical objects, they would not demonstrate boundary extension because boundary extension necessitates a perception of how the scene exists elsewhere in the world, beyond the edges of the photograph. After first and fifth-graders were shown photographs, they were instructed to draw what they had seen as accurately as possible from memory. This research provided evidence that children as young as six demonstrate significant boundary extension, as they drew images with extended backgrounds and smaller objects than were presented in the stimuli (Seamon et al., 2002).

Further, Candel, Merckelbach, Houben, and Vandyck (2004) found that children aged 10 to 12 years old demonstrate boundary extension for both neutral and emotional pictures. Researchers wondered whether emotional photographs would affect boundary extension demonstrated in children. Children were presented two types of pictures: emotional and neutral images. Emotional scenes involved frightening and arousing pictures, such as sharks or snakes. Neutral pictures included a toy bucket and bananas. Children demonstrated boundary extension when recalling what they remembered seeing by drawing from memory for both emotional and neutral pictures. Children drew smaller objects and added more expansive surrounding backgrounds than were presented as stimuli for both emotional and neutral scenes, indicating boundary extension. The amount of boundary extension in drawings did not differ between neutral and emotional conditions. This research is further evidence that
older children act similarly to adults, demonstrating boundary extension when recalling photographs of various scenes (Candel, et al., 2004).

While these studies demonstrate the existence of boundary extension in children of various age groups, there are methodological limitations that must be considered. These studies rely on drawing tasks, and the nature of such tasks may have affected results. For this reason, Kreindel and Intraub (2017) developed a two-alternative forced choice task for 4-5 year-old children. Kreindel and Intraub (2017) decided to investigate this phenomenon in children aged 4 to 5 years, because of Liben’s (2008) work on young children and photo-literacy. As previously described, this work demonstrated that around the ages of 4-5 years, young children are just beginning to develop an understanding of photo-literacy concepts (Liben, 2008).

Kreindel and Intraub (2017) noted that results taken to indicate the presence of boundary extension in children based on drawing tasks may have been the result of drawing artifacts rather than the result of memory phenomena. It is possible that children tested were incapable of drawing large objects due to preference, drawing ability, or small hand size. Drawings that seemed to represent boundary extension may have actually been due to inability to accurately represent the child’s memory for the photograph. For this reason, Kreindel and Intraub (2017) created a two-alternative forced choice recognition experiment for 4 to 5 year-old children that did not rely upon drawing at all. The experiment involved a recognition task with physical cards. Researchers created picture pairs showing both a close-up and wide-angle view of the same scene—for example, a cat in a room (see Figure 1). Children were presented with a card containing a target view (either a close-up or wide-angle view) for 15 s. Then, after a 2 s interim period, a new card was revealed containing both views.
Children were asked to select which of the two viewpoints they had previously been shown. (Kreindel & Intraub, 2017).

![Trial Sequence](image)

**Figure 1** **Trial Sequence**, Participants were first shown a stimulus card with a target view, then there was a 2 s interim where the cards were flipped over. Then participants were shown a response pair and asked to indicate which view they were just presented.

Kreindel and Intraub (2017) reported that, when comparing trials with a close-up target and a wide-angle target, children most often made errors when the target was the close-up view. In this case, children incorrectly reported having seen a wide-angle view. Because a wide-angle photograph depicts more of the real-world scene than a close-angle view, an incorrect wide-angle choice suggests that children anticipated how the scene continued beyond the boundaries of the photograph and remembered this anticipation as having been part of the visual stimuli presented in the original
photograph. When the target was a wide view, however, children tended to correctly select the wide view on the response card. We expect children to choose the correct photograph when the target was a wide-angle photograph because even if children got some boundary extension in this condition, the wide-angle photograph is still the better choice—boundary extension would make the close-angle photograph appear far to close-up and notably incorrect. These findings suggest that 4 to 5 year-old children experience boundary extension. A guessing game task indicated that these results did not reflect a simple bias or preference for wide-angle photographs. When children were asked to guess which view (closer or wider) that a confederate was looking at (out of participants’ view) for 12 trials, children did not show a preference for the wide-angle views (Kreindel & Intraub, 2017).

Kreindel and Intraub’s (2017) work can be taken to indicate that young children do understand the dual representation associated with physical photographs. Performance on the matching task indicates the presence of boundary extension, because children often incorrectly selected the wide-view photograph as what they were presented when in reality they were presented a close-view of a scene. Children even demonstrated boundary extension for complex photographs where adults rarely made any mistakes at all. These findings indicate that children of this age make more reality monitoring errors while recalling photographs of scenes than do older children or adults (Kreindel & Intraub, 2017).

Sheehan and Uttal (2016) state that more research is necessary regarding children’s use of touchscreen tablets and their ability to understand the representative nature of entities presented on tablets. Because the presence of boundary extension relies upon an understanding of the symbolic nature of photographs, we can use
boundary extension tasks on tablets to investigate whether young children also understand dual representation when conceptualizing digital images. Boundary extension necessitates an understanding of the symbolic nature of photographs, because if photographs are seen simply as objects themselves, the brain would have no means for extrapolating anticipatory information of how the scene would continue in the real world. It is this anticipatory information that results in the boundary extension phenomenon. Therefore, we will use boundary extension as a means of testing whether young children understand dual representation for both physical and digital photographs.
Chapter 2

PRESENT RESEARCH

Sheehan and Uttal (2016) raised concerns regarding children’s ability to understand the symbolic nature of images presented on screens, advocating for more research. The purpose of the present research is to utilize boundary extension as a means of testing whether photographs presented on a touchscreen interfere with children’s ability to understand the representative nature of such photographs. We are concerned that children may not perceive digital images in the same way that they perceive physical images. Are children able to understand digital images as both objects themselves, and also symbolic representations of real-world entities?

We conducted three experiments contrasting performance on two-alternative forced choice memory task using both physical and digital versions of the same photographs. We use findings from these experiments to determine whether participants’ responses indicate the presence of boundary extension. The presence of boundary extension is used to determine whether children understand the dual representation associated with photographs presented. In all cases, Kreindel and Intraub’s (2017) stimuli and test procedure were used. Experiments 2 and 3 were follow-up experiments motivated by the findings of Experiment 1. We will begin by presenting Experiment 1, and the motivation for Experiments 2 and 3 will be forthcoming.

Experiment 1

Experiment 1 investigates this question by replicating Kreindel and Intraub’s (2017) experiment using both physical photographs on cards and digital photographs presented on a touchscreen tablet. Both types of trials utilize 15 s presentation of the
target image. Rationale for this experiment is as follows: If children’s perception of the photographs of scenes is the same regardless of whether photographs are presented on cards or on a touchscreen, we would expect to replicate Kreindel and Intraub’s (2017) findings in both conditions. In contrast, if presenting photographs on a touchscreen interferes with children’s perception of dual representation, then we would expect to replicate Kreindel and Intraub (2017) for the card condition, but not when the images are presented on the touchscreen.

Method

Participants

Forty-three 4-5 year-old children enrolled at the Early Learning Center of the University of Delaware were invited to participate in this study. All participants were typically developing native English speakers. Children aged 4.17 to 5.11 years old were included in this study ($M=4.66$ years old). 10 males and 14 females participated. Children were distributed to each of 8 counterbalancing conditions to try to equate the conditions in terms of age and gender (see Appendix for counterbalancing chart). A criterion test was utilized to determine whether each child understood the differences between pictures of the same scene with differing views. 18 children did not pass the criterion task, so 25 children were included in the experiment. One child was replaced because the child chose the bottom photograph on the response set for every trial.

Materials

The stimuli were the same as in Kreindel and Intraub’s (2017) low-similarity condition. The wide-view photographs were zoomed out by 30% more than close-views, such that the objects became smaller and were surrounded by more
background. Like in Kreindel & Intraub’s (2017) study, target photograph cards and consisted of one 3” x 3” (7.62 x 7.62 cm) color digital photograph of a simple scene. For this experiment, each photograph was presented on either a physical card made of cardstock or a digital image on the touchscreen. The close-angle and wide-angle view of each scene was printed to serve as targets in the experiment. Response photographs consisted of two 3” x 3” (7.62 x 7.62 cm) color photographs of simple scenes, vertically aligned on a single card that was either printed on cardstock or presented digitally on the touchscreen. Response photograph cards were printed twice—once with the close-up view on top, and once with the close-up view on the bottom.

![Target and Response Photographs](image)

**Figure 2** *Target and Response Photographs*, The cupcake on the left is an example of a close-up target, and the vertical alignment of two views of the same cupcake on the right is an example of what a response pair looked like.

Most scenes included one main object against a natural background, such as a truck parked outside. Four scenes contained a single object-cluster on a background, such as a tower of dice against a door. The stimulus set for the memory task consisted
of 40 scenes, split into Set A (20 scenes) and Set B (20 scenes). Additional scenes of a similar type were included for the criterion and guessing game tasks. 6 additional scenes were included in the criterion task, and 12 additional scenes were included in the guessing game task.

The experimenter used the iPhone app Multitimer to time display of the target photograph in the card condition for 15 s. The iPhone was held in the experimenter’s lap, out of sight to children. The timer vibrated rather than made a noise as to not distract participants. For tablet trials, an Asus Memo Pad tablet was used. The tablet was situated inside a rubber bumper case for protection. An OpenSesame program was designed to display 3” x 3” target photographs, and response photographs with the same layout as response photograph cards. The program was designed to display target photographs for 15 s, show a 2 s mask, and then present the response photographs.

**Design and Procedure**

**Design**

The experiment consisted of 40 trials, split into two sessions of 20 trials each: a physical photograph (card) condition and a digital photograph (tablet) condition. Sessions lasted approximately 20 minutes, and were separated by a minimum of one day and separated by a maximum of 7 days. The conditions were counterbalanced across participants, such that 12 participants took part in the card condition first, and 12 took part in the tablet condition first. The order of scenes presented was kept the same for each session, as 20 scenes used for one session were always presented in the same order, as were the 20 scenes used for the other session. We also counterbalanced which 20 scenes were presented as cards and which were presented as digital images,
and within that, we counterbalanced whether the target view for each scene was a close-up or wide-angle target picture. Thus there were 8 counterbalancing conditions with 4 children assigned to each one. The counterbalancing can be described as 2 (card condition or tablet condition first) x 2 (which picture set is presented as cards vs tablet) x 2 (which scenes are presented as a close or wide target). Half the trials were close trials, in which the target photograph depicted a close-angle view. Half of the trials were wide trials, in which the target photograph depicted a wide-angle view. There were four counterbalancing orders to ensure that each scene appeared equally as often as a close-up or wide-angle view.

For example, in Order 1, the ‘cat scene’ target was close-up, while in Order 2 the ‘cat scene’ target was the wide-angle view. Orders 3 and 4 were identical to Orders 1 and 2, respectively, but the photos shown for the first session in these trials were shown as the second session for their complementary Orders. Participants were assigned to conditions in such a way that male and female participants equally participated in each trial type. Children’s ages were also taken into consideration to ensure that children of varying ages were included in each counterbalanced group.

Procedure

During Session 1, all participants took part in a perceptual matching task. This criterion task was always administered using photograph cards that were of a similar type to those in the 40 scene stimulus set, but that were never included in the main experiment. This task was developed to ensure that participants included in the experiment were able to match a target photograph to the corresponding wide-angle or close-up view on a response card when the target and response pair were simultaneously visible. Participants had to correctly match 5 out of 6 scenes in order to
be included in the experiment. This is because, if a child could not correctly do the task while perceiving the images, there would be no reason to expect that they would be able to complete the task from memory. Failures could include children not understanding the instructions, or choosing not to follow the instructions. Eighteen children failed the criterion task. Kreindel and Intraub (2017) reported a 100% pass rate on the same criterion task. This discrepancy may be due to changes in recruitment requirements for students at the Early Learning Center (ELC). The ELC now accepts students with no prior daycare experience, a new policy since the previous experiment.

Upon passing the criterion task, participants completed the experiment in either a card or tablet session. This part of the experiment involved a two-alternative forced choice recognition memory experiment, replicating the experiment conducted by Kreindel & Intraub (2017). On each trial, the target photograph was presented for 15 s, on either a physical card or the tablet depending upon which session was being conducted. The experimenter and subject discussed the photograph, looking at the main object and also describing the surrounding background of the scene. The subject was instructed to remember everything about the scene presented, and to ‘take a picture’ of the scene with his or her “brain camera”. Together, the experimenter and subject counted to three and said ‘click’ to simulate taking a picture with a camera. There was a 2 s interim period in which either the target card was flipped over, or a mask consisting of gray curvy lines was presented on the tablet. A mask was included in the tablet condition because flipping over the physical photographs created a 2 s interval between studying the target and recalling a scene using the response card. The mask was put in place to provide a 2 s interval between presentation of the target and response photographs to replicate the conditions of the physical photograph sessions.
Next, the two test choices were presented, and participants were asked to select which scene they remembered previously seeing. It was planned that if participants were observed to be losing interest or focus, a monkey finger puppet would be presented. However, this was never required. Some participants took very short breaks to move around a bit or to do jumping jacks.

In session 2, participants received the 20 scenes that they did not view in session 1. Before beginning the task, participants were reminded of session 1. The experimenter prompted with, “Do you remember the game we played together last time? We looked at pictures then used our brain cameras to remember everything about the pictures”, then explained that the same game would be played using different media. (If participants used cards in session 1, they would use the tablet in session 2). Participants completed the same recognition memory experiment as in the previous session.

**Figure 3** Trial Type, The left image shows what card trials looked like, while the right image shows what images presented on the tablet looked like.
Upon completion of 20 trials in session 2, participants participated in a guessing game administered on the tablet. The reasoning for the guessing game was to ensure that participants did not simply have a bias for picking either a close-up or wide-angle view in order to validate their responses. The guessing game consisted of 12 trials, counterbalancing whether the close-angle view or wide-angle view was presented on top. The tablet presented a question mark for 15 s. During this time, the experimenter explained that the tablet was ‘hiding’ a picture. The experimenter and participant speculated about what the tablet might be hiding a picture of. After 15 s presentation, a 2 s mask was presented, followed by two vertically aligned photographs of the same scene—a close-up view and a wide-angle view. The participant was asked to guess which picture the table was hiding. This information was used to determine whether the participant had a bias for selecting a certain view of a scene.

Results and Discussion

A proportion of errors was calculated to represent each participant’s performance on both close trials and wide trials. For each participant, the number of incorrect answers, out of 20, was calculated for both close and wide trials. Then, means were taken to find the average proportion of errors in each condition. The proportion of errors as a function of trial type made by each child is presented in Figure 4. The confidence intervals show that children made a statistically significant number of errors on card presentations, but results were not significantly different for tablet presentation. In the card condition, children struggled to correctly select the close-up photograph when the target was close-up, indicating boundary extension. In this case, children’s responses demonstrated the ability to understand that the
photograph represented a scene elsewhere in the world. Children did not make so many errors when recalling wide-angle views, validating the boundary extension phenomenon. These results directly replicate Kreindel and Intraub (2017). For card trials, these errors were significant and were not due to chance. For tablet trials, there was no significant difference in the proportion of errors made when comparing close and wide trials.

Figure 4  **Memory Task Errors**, Indicates the proportion of errors made on close and wide trials in both card and tablet conditions. Error bars show the 0.95 confidence interval around each mean.

A 2 (order of presentation) x 2 (cards vs tablet) x 2 (close vs wide) Mixed ANOVA demonstrated that there was a main effect of close vs wide trial type which was significant, F(1, 22) = 14.05, \( p < .001 \), \( \eta^2_{p} = .39 \). The main effect of presentation type x trial type interaction was also significant, F(1, 22) = 20.66, \( p < .0002 \), \( \eta^2_{p} = .48 \). The order of presentation had no significant main effect, F < 1 in all cases. These results indicate that regardless of the order of presentation, children reacted differently
to close-up and wide-angle photographs depending upon the way that these photographs were presented.

For the card presentation condition, 87.5% of participants (21 out of 24 children) made more close trial errors than wide trial errors. This pattern is expected when boundary extension occurs, because incorrectly selecting the wide-angle view when the close-angle view was the target shows that participants remember having seen more of a view than was actually presented. For the tablet presentation condition, only 62.5% of participants (15 out of 24 children) made more close trial errors than wide trial errors—the expected pattern for boundary extension. In this condition, 9 children actually made more errors on wide trials than on close trials, which is not expected if boundary extension occurs.

Guessing game results indicate that overall, children did not show a preference for either the close-up or wide-angle photographs. The mean number of wide-angle choices was M=6.5, SD=2.45, while the mean number of close-angle choices was M=5.5, SD=2.45. A t-test indicates no significant difference, t(23) = -0.92, p = 0.37. In sum, this guessing game task is a critically important control which further validates the findings of the memory task. The results of this guessing game task argue against the possibility that the small error rates for wide trials occurred due to a general preference for selecting wide photographs.

Our results in the card condition clearly replicated Kreindel and Intraub’s (2017) findings. This experiment included the same group of children in each condition. Therefore, the exact same children that replicated Kreindel and Intraub’s (2017) boundary extension findings in the card condition failed to, as a group, exhibit boundary extension while using a tablet. For the card condition, only 3 out of 24
children did not show the expected pattern for boundary extension—only 3 children did not make more close-trial errors than wide-trial errors. However, in the tablet condition, 9 of 24 children failed to show the expected pattern. In the case of the tablet condition, where the group of children did not demonstrate clear boundary extension, it is important to note that children were incorrect. Instead, during the tablet condition the very low error rate for wide trials increased.

Our results indicate that children do not conceptualize photographs presented on touchscreen tablets in the same way that they conceptualize physical photographs. These findings may provide evidence that children are not able to understand the symbolic, representative nature of such photographs. 4 to 5 year-old children may be inclined to understand these photographs as object themselves, but struggle to link these objects to their real-world referents. We further investigate these findings with two follow-up experiments: one that explores a relatively low-level perceptual account of the tablet results (Experiment 2), and the other an account at a more conceptual level (Experiment 3).

**Experiment 2**

Experiment 2 tests the hypothesis that the failure to observe boundary extension in the tablet condition might have to do with the close proximity of the photographs’ borders to the borders of the touchscreen itself. This may have distracted children, or disrupted children’s perception of the photograph as a representation of a place in the world, therefore interrupting with the brain’s automatic generation of the anticipated world beyond the view. In the card condition, any borders aside from the borders of the photographs themselves were much farther away from the photograph, as the photographs were displayed laying on a smooth tabletop. In the present
experiment, physical cards will now lay on top of the touchscreen so that the border situation will replicate the border situation presented when digital images are presented on the tablet. This time, however, children will have to complete the task under the same border situation using physical cards. If the proximity of borders was the issue in the previous experiment, then we should not find boundary extension using the physical cards in this experiment because the same border issue is presented. However, if digital presentation is somehow interfering with dual representation, and the issue is not due to the proximity of borders, then we should replicate previous findings of boundary extension while using physical cards even if they are presented near other close borders.

Method

Participants

Forty children enrolled at the Early Learning Center of the University of Delaware were invited to participate in this study. All participants were typically developing native English speakers. Children aged 4.0 to 4.91 years old were included in this study ($M=4.43$ years old). 11 males and 13 females participated in this study. Gender and age were evenly distributed across 8 counterbalancing groups (see Appendix). We set out to conduct Experiments 2 and 3 using the available children who fit our specifications at the Early Learning Center. Therefore, we counterbalanced the order of Experiments 2 and 3 so that children could be included in both experiments without creating an order effect. As in Experiment 1, a criterion test was conducted before each of these experiments. Some children passed one criterion task and not the other. Therefore, across Experiments 2 and 3, 19 children passed both
tasks and were included in both experiments, 5 children were included only in Experiment 2, and 6 children were included only in Experiment 3. Therefore, 24 children were included in the memory task for Experiment 2.

**Materials**

The same materials as were used in Experiment 1 were used in Experiment 2, with the exception that 2 additional practice scenes were printed for the criterion task. Therefore, the new criterion task consists of 2 additional practice scenes and 6 test scenes.

**Procedure**

Experiments 2 and 3 were conceptualized and reported as separate experiments, as they investigate different research questions. However, the two experiments were counterbalanced for the purpose of data analysis, as described above. Participants who were included in both experiments saw one set of 20 photographs in Experiment 2, and saw the other half in Experiment 3. Half of all trials were close trials, in which the target photograph depicted a close-angle view. Half of the trials were wide trials, in which the target photograph depicted a wide-angle view of the scene. Participants were assigned to these experiments in such a way that male and female participants were equally included in each experiment. Sessions lasted approximately 20 minutes, and participation in each experiment was separated by a minimum of 1 day and a maximum of 7 days.

In this experiment, participants had to complete the same perceptual matching task as was presented in Experiment 1. The only exception is that in this experiment, 2 practice trials were completed before the 6 test trials. This was done in attempt to
lessen the failure rate. On the two practice trials, children were shown the target photograph alongside the test-pair and asked to indicate which one was the same as the target. After responding, children were given feedback regarding their answer, and the experimenter indicated differences in the views of the scenes by discussing which photograph made the key object look larger and which photograph made the key object look smaller, while also directing the children’s attention to the backgrounds up to the edges of the photograph by pointing. Then, children completed the same criterion test as was administered in Experiment 1. Of 40 children invited to participate in Experiment 2, 24 passed the criterion task. Fifteen children received a score of 5/6 correct matches, and 9 children received a score of 6/6 correct matches. Upon passing the criterion task, participants completed a recognition memory experiment replicating the task outlined in Experiment 1. Following the memory task, participants completed the 12-scene guessing game task, which was the same as described in Experiment 1.

Results and Discussion

The proportion of errors as a function of trial type made by each child is presented in Figure 5. For close trials, M=0.655, SD=0.19, and N=24. For wide trials, M=0.09, SD=0.12, and N=24.
Participants’ mean proportion of errors on close trials, M=0.66, is significantly different than participants’ mean proportion of errors on wide trials, M=0.09, according to a two-tailed paired samples t-test, t(23)=12.53, p < .0001, dz= 2.56. One participant selected wide-view photographs 100% of the time during the memory task. Therefore, we will also present the results with this participant excluded. In this case, participants’ mean proportion of errors on close trials, M=0.64, is significantly different than participants’ mean proportion of errors on wide trials, M=0.09, according to a two-tailed paired samples t-test, t(22)=12.77, p < .0001, dz=2.66. Inspection of the pattern of errors showed that 100% of the children showed the expected pattern, making more errors on close than wide trials. This pattern is expected when boundary extension occurs. All participants made more errors on close trials than on wide trials, indicating boundary extension.
The guessing game task was administered following completion of the memory task in order to ensure that participants were not simply selecting wide-angle photographs during the memory test because they preferred them—making choices based on preference rather than memory. Therefore, the guessing game is a way of validating memory task responses. Guessing game results indicate that overall, children did not show a preference for either the close-up or wide-angle photographs. The mean number of wide-angle choices was M=5.71, SD=1.57, while the mean number of close-angle choices was M=6.29, SD=1.57. A t-test indicates no significant difference, t(23)= 0.91, p = 0.37. In sum, the results of this guessing game task argue against the possibility that the small error rates for wide trials occurred due to a general preference for selecting wide-angle photographs.

The results of Experiment 2 closely replicated the results of the physical card condition in Experiment 1. Clearly, nearby borders do not interfere with boundary extension. In Experiment 2, we replicated Experiment 1’s physical card condition. However, in Experiment 2, these cards were presented laying on top of a blank tablet screen. In doing so, we were able to determine whether the problem with the tablet condition in Experiment 1 was due to the proximity of nearby borders. Because children did continue to demonstrate boundary extension in this condition, we can eliminate the possibility that the close proximity of multiple edges present in tablet conditions is the cause of the lack of boundary extension previously found for the tablet condition.

**Experiment 3**

In Experiment 3, we tested the possibility that when digital photographs are presented on a touchscreen tablet, something about this presentation affects the way
that children represent scenes in their minds. Perhaps, in Experiment 1, children did not demonstrate boundary extension in tablet sessions because the presentation of photographs on tablet screens interferes with children’s ability to achieve dual representation. Perhaps the conceptualization process for digital photographs differs from conceptualizations of physical photographs. This difference in conceptualization may impede young children’s ability to understand the symbolic nature of digitally-presented images. This experiment draws on relevant research literature which presents reason to believe that assisting children in conceptualizing symbolic entities appropriately allows children to better understand the dual representation associated with such entities.

DeLoache, Miller, and Rosengren (1997) investigated 2.5 year-old children’s ability to think about and understand symbolic representations with a classic experiment entitled “The Credible Shrinking Room”. The researchers assert that similarity between symbols and their referents requires one to achieve dual representation, or the understanding that a symbol is both a concrete object itself and also a reference to something other than itself. Further, a highly salient symbol may make it difficult for children to understand the abstract reference of the object. (DeLoache et al., 1997). Because children are interacting with our photographs on a touchscreen, the salience of these images is high—it is easy to understand that these images are objects on the tablet because of interaction with the images. This salience may in turn make it difficult for our participants to understand that these photographs also represent larger scenes in the real world.

DeLoache, Miller, and Rosengren (1997) designed their experiment in an attempt to understand how children reacted to symbolic and non-symbolic
representations. Children had to use information regarding where a toy was hidden in one area in order to find that toy in another area. In one task, children were simply shown where the toy was hidden in a small model room. They were then asked to find the toy in a life-size room which exactly replicated the model. This task represents the need for symbolic representation, because children must understand that the model room represents the larger room in order to find the toy. In the non-symbolic task, children were made to believe that the model room was the larger room, after having been shrunk in a shrinking machine. This task does not require dual representation, because children understand that the model and the large room simply are the same thing, making the task only a task of memory (DeLoache et al., 1997).

DeLoache, Miller, and Rosengren (1997) found that children made many more errors during toy retrieval when performing the symbolic task than when performing the non-symbolic task. Children were much more successful in finding the toy when they understood the large room and the model room as being the same entity. This result demonstrates that children have difficulty understanding symbolic relationships and achieving dual representation; understanding the link between symbols and their referents can be a difficult task. This trouble may occur because it is difficult for children to keep two separate representations active in the mind simultaneously, and it is especially difficult to represent one symbol in multiple ways (DeLoache et al., 1997). These findings are reason for concern that children may have difficulty representing images on tablet scenes not only as an object within the tablet, but also as a photograph which symbolically represents a view of the world.

If children did not demonstrate boundary extension during tablet sessions in Experiment 1 because touchscreen tablet presentation of photographs interferes with 4
to 5 year-old children’s ability to achieve dual representation for digital images, then making children think that the images on the tablet screen are themselves physical cares might result in the demonstration of boundary extension. In thinking of digital images as physical photographs, children may be more likely to understand that these images are symbolic and represent scenes in the real world, rather than only existing as objects themselves. This understanding would result in the demonstration of boundary extension, because children’s brains would begin to extrapolate anticipatory information by drawing on how the scene is likely to exist in the real world.

Using similar reasoning as was used in DeLoache’s (1997) Shrinking Room experiment, researchers aim to help children think of tablet images not just as an object on the tablet, but rather as a physical photograph that also represents a scene in the world. Researchers will “magically” insert physical photograph cards into the tablet and explain that the image on the tablet screen is the card that was just inserted into the tablet.

Method

Participants

Forty children enrolled at the Early Learning Center of the University of Delaware were invited to participate in this study. All children were typically developing native English speakers. Children aged 4.0 to 4.83 years old ($M=4.41$ years old) participated in the study. 13 males and 12 females participated. As in previous experiments, children were assigned to counterbalancing groups such that age and gender were distributed evenly (See Appendix). The same criterion task as was utilized in Experiment 2 was utilized in Experiment 3, with the exception that
response cards were now displayed as digital photographs on the tablet. This was done to ensure that children included in the experiment were able to determine the differences between photographs of the same scene taken from different vantage points when these photographs were presented digitally. 15 children failed this criterion task, and therefore 25 children were included in the memory task.

Materials

The same materials from the criterion task, memory task, and guessing game task in Experiment 2 were used in Experiment 3. In this experiment, the tablet was lifted slightly from the table by gluing corkboard strips to the bottom of the tablet. This was done to allow room to slide physical photograph cards underneath the tablet, telling children that these cards were actually being inserted inside the tablet. The experimenter also used a glitter-filled “magic wand” in order to demonstrate a magic trick to the children that made the physical cards show up on the tablet screen. The experimenter slid physical photograph cards underneath the tablet, then used the magic wand while clicking the tablet to make it appear as though the physical card just appeared digitally on the tablet screen.

Procedure

As explained previously, Experiments 2 and 3 were conceptualized and reported as separate experiments, as they investigate different research questions. Experiment 3 involved the same counterbalancing described in Experiment 2 (See Appendix).

In this experiment, participants had to complete the same perceptual matching task as was presented in Experiment 2, with the only difference being that this
criterion task was administered on the tablet with digital images. The tablet screen was not large enough to present both the response pair and target photograph simultaneously, so the response pair was presented digitally while the target photograph was presented using a photograph card that the experimenter held next to the screen. Of 40 children invited to participate in Experiment 3, 25 passed the criterion task. 14 children received a score of 5/6 correct matches, and 11 children received a score of 6/6 correct matches.

Upon passing the criterion task, participants completed a recognition memory experiment replicating the task outlined in Experiments 1 and 2. The difference here was that physical photograph cards were “inserted” under the tablet to give the effect that they were being put inside the tablet. The experimenter explained that she brought her magic wand and would perform a magic trick in which she inserted the cards into the tablet and made those same cards show up on the tablet screen—effectively encouraging children to understand the digital images as physical photographs.

Once the card was slid under the tablet, the experimenter said “abracadabra” and clicked the tablet to make the digital image show up while simultaneously tapping the tablet with the magic wand. The target image was presented for 15 s and was discussed between the experimenter and the subject. The experimenter included prompts such as “There is the card!” and “What can you see on that card?” to further encourage children to conceptualize this image as a physical card. Participants were instructed to remember everything about the photograph, including the size of objects. Again, the experimenter and subject counted to three and said ‘click’ to simulate taking a picture with a camera. There was a 2 s interim, during which a mask screen was presented. The experimenter again tapped the tablet with the magic wand before
the response photographs appeared, and participants were asked to indicate which photograph they remembered seeing.

Similar to Experiment 1, Experiment 3 ended with a guessing game task, in which participants guessed which view, a close-up or wide-angle view, the tablet was hiding after viewing a question mark for 15 s. This test designed to determine whether the children had a preference for either a wide-angle or close-angle photographs, validating their responses as memory recall rather than preference.

Results and Discussion

The proportion of errors as a function of trial type made by each child is presented in Figure 6. For close trials, $M=0.57$, $SD=0.19$, and $N=25$. For wide trials, $M=0.16$, $SD=0.14$, and $N=25$.

![Figure 6 - Memory Task Errors] Figure 6: Memory Task Errors, Indicates the proportion of errors made on close and wide trials in Experiment 3. Error bars show the 0.95 confidence interval around each mean.
Participants’ mean proportion of errors on close trials, M=0.57, was significantly different than participants’ mean proportion of errors on wide trials, M=0.16, according to a two-tailed paired samples t-test, t(24)=7.24, p < .0001, \(d_z = 1.45\). One participant selected the wide-view photographs 100% of the time during the memory task. Therefore, we will also present the results of the experiment with this participant’s data excluded. In this case, participants’ mean proportion of errors on close trials, M=0.55, was significantly different than participants’ mean proportion of errors on wide trials, M=0.16, according to a two-tailed paired samples t-test, t(23)=7.23, p < .0001, \(d_z = 1.48\). Nearly all participants, 96% (24 out of 25 participants), in Experiment 3 made more close trial errors than wide trial errors, the expected pattern that indicates boundary extension. Only one child in this experiment made more errors on wide trials than close trials.

The guessing game task was administered following completion of the memory task in order to ensure that participants were not simply selecting wide-angle photographs because they preferred them—making their choices based on preference rather than memory. Of the 25 participants in this experiment, one participant did not complete the guessing game task because this participant did not accept the invitation to participate in a follow-up portion of the study. Therefore, 24 participants were administered the guessing game task. Guessing game results indicate that overall, children did not show a preference for either the close-up or wide-angle photographs. The mean number of wide-angle choices was M=5.83, SD= 1.71, while the mean number of close-angle choices was M=6.17, SD=1.71. A t-test indicates no significant difference, t(23)= 0.48, p = 0.64. The results of this guessing game task validate findings of the memory task, arguing against the possibility that the small error rates
for wide trials occurred due to a general preference for selecting the wide-angle photographs. The guessing game task showed no difference in preference for close-angle or wide-angle photographs.

In sum, findings from Experiment 3 demonstrate that encouraging children to conceptualize digital images as physical photograph cards results in the emergence of boundary extension for digital tasks. When the “magic trick” intervention was applied to the memory task, boundary extension appeared for the tablet condition. These findings suggest that something about the touchscreen presentation of photographs interferes with young children’s conceptualization of such photographs. Children may have difficulty relating photographs on screen to real-world referents, therefore not exhibiting boundary extension for digitally-presented photographs. However, conceptualizing these same photographs as physical cards alleviates this difficulty.
Chapter 3

GENERAL DISCUSSION

The three experiments conducted for this research study demonstrate important findings. Results of Experiment 1 replicate Kreindel and Intraub (2017) for the card condition, but not for the tablet condition. This indicates that something about the tablet condition was interfering with children’s conceptualization of these photographs. Experiment 2 sought to determine whether the issue with the tablet condition arose due to the proximity of nearby borders by laying physical photograph cards on top of the tablet screen. Results from Experiment 2 also replicated Kreindel and Intraub (2017), indicating that the nearby borders introduced in this condition were not the reason behind children’s lack of boundary extension for the tablet condition. Experiment 3 asked whether the reason behind children’s difficulty with the tablet condition was due to inability to correctly conceptualize digital photographs. By using a “magic trick” to make children believe that digital images were physical photograph cards, we were able to aid children’s conceptualization of digital photographs, which resulted in the emergence of boundary extension for digital images.

Boundary extension is a phenomenon that results when the brain’s automatic scene construction processes generate anticipatory information of how a scene continues beyond the given view. This information is then subject to a reality monitoring error, in which one misremembers having actually seen what was really just the brain’s generated anticipation of what might lie beyond the boundaries of a view (Intraub, 2010). If these children demonstrate boundary extension when tested for memory of photographs of scenes, we can assume that these children understand
that the images are not just objects themselves but, importantly, are also symbols that represent a scene in the real world. If children do not demonstrate boundary extension, they likely do not understand the photographs as symbols and therefore do not make errors remembering close-up photographs. In this case, children do not recognize that the photograph symbolically represents a real-world scene and therefore do not anticipate how the scene would continue in reality. Therefore, we can use boundary extension as means of testing whether young children understand the dual representation associated with photographs of scenes.

Four to five year-old children are included in this research because research regarding the development of photo-literacy suggests that children of this age are just beginning to develop a mature understanding of photographs (Liben, 2008). This information also enables educators to understand the most effective ways to teach important concepts to young children. Previous research expresses concern over young children’s ability to understand the symbolic nature of referents when these referents are presented digitally. We use boundary extension as a way of testing whether these young children understand the dual representation that is associated with photographs of scenes. Our results from Experiment 1 lead us to consult relevant literature regarding young children’s ability to identify the symbolic nature of photographs as referents and to learn from touchscreen presentation of information.

Uttal, O’Doherty, Newland, Liu Hand, and DeLoache (2009) explain that linking different representations of symbols, or achieving dual representation, is difficult for young children. If dual representation is more difficult to achieve when viewing content presented on screens, implications for education must be considered (Uttal, et al., 2009). An inability to correctly interpret the spatial properties of images
can affect learning in the STEM disciplines (Newcombe & Frick, 2010). If children are unable to correctly perceive digital images, perhaps the growing presence of educational tools which involve screens is inhibiting children’s ability to understand these concepts.

Uttal and colleagues (2009) assert that using symbols effectively requires one to focus more on what the symbol represents than on the symbol itself, which may prove difficult for young children. Further, the more salient a symbol becomes, the more difficult it is for children to appreciate the symbol as a representation of another entity. On the contrary, when a symbol’s object properties are less-salient, it becomes easier to recognize the symbol as not only an object itself, but also as a representation of something else. This difficulty is directly related with STEM education, as concepts in these disciplines often require the understanding of symbolic representations (Uttal et al., 2009). Because touchscreen images themselves are representations of photographs, and photographs are representations of scenes in the real world, screen presentation may interfere with scene extrapolation. Due to this additional representational level, the use of screen technology for education may hinder young children’s ability to conceptualize the symbolic concepts found in STEM disciplines.

Uttal and colleagues (2009) suggest that touchscreen programs designed to aid children’s learning might actually hurt learning processes in cases where the screen presentation makes it more difficult for children to relate symbols to their referents. Children have difficulty transferring knowledge from symbols such as manipulatives to other representative forms (Uttal et al., 2009). It is possible that due to the salience and manipulation of symbols presented on touchscreens, children have
a tendency to focus on these symbols as objects themselves and do not readily understand the link between these symbols and their referents.

Further, these findings may have implications for education. Moser, Zimmerman, Dickerson, Grenell, and Gerhardstein (2015) investigate whether toddlers are capable of transfer learning from screens. Transferring knowledge from 2D contexts such as screens can be difficult, as this task relies upon cognitive flexibility. Touchscreen images might be confusing because the images themselves are 2D, while the tablet as a whole is three-dimensional. In this experiment, 2.5 and 3 year-old children participated in a puzzle task after an experimenter demonstrated how to complete the puzzle using either physical 3D pieces or a touchscreen. After viewing the demonstration three times, children were given the opportunity to manipulate the puzzle pieces as either physical 3D pieces or on a touchscreen. When children viewed a 2D demonstration, they performed more poorly on the puzzle task. In a follow-up experiment that included video demonstration, children continued to demonstrate a transfer deficit from both touchscreen and video demonstrations. Researchers conclude by claiming that memory limitations may make it difficult for young children to equate cues across differing dimension (Moser et al., 2015). These findings suggest that children may inherently understand 2D and 3D stimuli quite differently, and have difficulty understanding associations between the two.

Expanding upon findings from Experiment 1, Experiment 2 assures us that the reasoning behind the absence of boundary extension for photographs in the tablet condition was not the proximity of nearby borders. Experiment 3, which investigates the problem at a more conceptual level, finds that encouraging children to conceptualize digitally-presented photographs as physical photographs themselves can
alleviate some of the difficulty associated with the mental representation of digital images. Drawing on relevant research literature regarding children’s use of symbolic representations, these findings suggest that young children may not have the conceptual ability to understand the symbolic nature of entities presented on touchscreen tablets.

DeLoache, Miller, and Rosen (1997) found that by eliminating the symbolic nature of a model as it relates to a real-world reference, young children were able to correctly find a hidden toy in a room after seeing where a scale-model of the toy was hidden in a smaller scale-model of the room. When the model’s symbolic nature was demonstrated to children, by telling children that the model was actually the shrunken large room, children were able to relate the model to the room. However, when this step was not taken, young children were not successful in finding a hidden toy in the large room based on information presented in the model (DeLoache et al., 1997).

In this experiment, we attempted to use similar thinking to this previous experiment in order to determine whether digital representation of photographs of scenes interferes with young children’s ability to understand the representative nature of the scenes, as tested by measuring the presence of boundary extension. In Experiment 1, children did not receive any assistance with conceptualizing the digitally-presented photographs as both objects themselves, and also as symbolic representations of scenes that exist somewhere in the real world. In order to alleviate the ambiguity of the symbolic nature of these images, we created a “magic trick” which we hoped would assist children in conceptualizing the photographs as symbolic entities. Using the “magic trick” allowed for children to conceptualize digitally-presented images in the same way that they conceptualized physically-presented
images. Children were excited by the “magic trick”, and made statements demonstrating that they believed in the “magic trick” often.

Our findings from experiments 1, 2, and 3 taken together lead us to believe that the digital presentation of photographs on a touchscreen tablet does interfere with children’s understanding of photographs as symbols. We know that children recognize physical photographs as symbols because findings from the card condition in Experiment 1 are consistent with boundary extension. However, children in the tablet condition did not demonstrate boundary extension. After ensuring that this was not due to the proximity of multiple borders, we corroborated our concerns raised in Experiment 1 with results from Experiment 3. Once children conceptualized digital images as physical photographs, boundary extension appeared for digital images. This result indicates that when digital photographs are presented, children do not understand them as symbolic referents. The screen presentation of images interferes with children’s mental representations.

Much research literature reports concern regarding the fairly recent trend in using educational technology to teach young children. Research spanning various content areas reports growing concern. Electronic educational tools may affect children’s learning in the domains of reading, math, and science. For example, Munzer, Miller, Weeks, Kaciroti, & Radesky (2019) observed 2 to 3 year olds’ reactions as parents read from either print or electronic books. These researchers found that young children were less engaged, making less verbalizations regarding the story, when they were read to from an electronic book (Munzer et al., 2019). Furthermore, research reports that reading on a tablet or computer screen results in worse recall of what was read, along with worse reading comprehension amongst older children.
(Dredge, 2015). These findings bring about questions regarding performance on tasks involving screens versus physical objects. Children may have an inhibited ability to understand the two natures of symbolic photographs when presented on screens.

This educational concern is particularly relevant for the STEM disciplines, as STEM learning often relies upon the interpretation of symbols, charts, graphs, and other images. Our results demonstrate that children do not readily understand the symbolic nature of digitally-presented entities. Therefore, caution must be used when utilizing screen-based technology to teach young children new concepts—particularly concepts that rely upon a symbolic understanding. Young children may not learn these concepts as effectively when images are presented digitally, which raises concern due to the prevalence of educational technology in today’s classrooms.
REFERENCES


Appendix A

EXPERIMENT PROTOCOL

Following, find documentation of the experimenter’s dictation and gestures while conducting the experiment.

“Hi there, _____ . How are you today? My name is Miss Heather. Today we’re going to play a picture game. Do you like to look at pictures? Okay, let’s start with a warm-up. [Show criterion warm-up card with two views of couch on it]. What is this a picture of? Good job! [Point to background of picture, up to edges of photograph] And what is this back here? What is over here? [Direct child’s attention to all areas of photograph]. Great job! These are both pictures of the same couch, but does one picture make the couch look bigger? Which picture makes the couch look bigger? [Give feedback depending on answer].

Great job, let’s try a matching game now! [Show first criterion response pair]. What is this a picture of? You’re right! [Use finger to draw attention to background of photograph up to the edges]. What is over here? What about over here? Good! [Flip over criterion target picture]. Now, can you tell me which of these [name objects in picture, indicating images on response card with finger] is the same size as this [point to target photograph, name object]? [Use finger to slide target photograph up and down next to response card, aligning photograph with the top picture and bottom picture on response card so that participant can see them side by side while trying to match images based on size]. Thanks! Let’s try another. [Repeat for all criterion pictures].

You did a great job. Should we try a new game, one that we have to use our memory for? Do you think you have a good memory? I bet you do! Before we begin,
let’s think about pictures. Have you ever seen someone take a picture before? They usually hold the camera like this [hold imaginary camera in front of face] and say ‘1…2…3…click!’ Then, the camera saves the picture! Do you think that we can use our brains like cameras to remember the pictures we see? When we are finished looking at a picture, we will take our brain cameras out like this [hold imaginary camera in front of face] and look at the picture while we say ‘1…2…3…click!’ Then we will remember everything about the picture in our brains!

For this game, our job is to remember everything we can see in the picture and we will use our brain cameras to help us! We have to remember the size of the object in the picture, and everything around it! I will show you one picture like this [use a criterion target photograph card that was already seen to demonstrate test sequence]. We will look at the picture together, and your job is to remember the size of the object in the picture, and everything around it [using finger to indicate background up to the edges of the photograph]. Then, I will flip the card over/lots of curly lines will appear (dependent upon whether in card or tablet condition), and then we will see a card with two of the photographs, like this one [show criterion task response card that was already seen to demonstrate test sequence]. Then, you have to tell me which picture is exactly the same size as the one we were just looking at. Are you ready?

[Present first target photograph]. What is this a picture of? You’re right! And what is this over here? And how about over here [using finger to focus child’s attention on the background up to the edges]? Okay, let’s get our brain cameras out so that we can remember everything about the picture! Ready? 1…2…3…click! [flip over cards or mask is presented, then present response pair]. Okay, which one of these
is exactly the same size as the picture we were just looking at? Touch it for me! Good job, let’s do another one. [Repeat for all 20 stimuli].

Great job! We have one more game to play. In this game, we don’t use our memory any more. Instead, we guess! The tablet is going to hide a picture, and you have to guess what it was hiding! Let’s try it. [Initiate first guessing game sequence on the tablet. 15 s mask with a question mark appears]. Okay, the tablet is hiding a picture. What do you think it could be hiding a picture of? [Discuss possibilities until mask appears]. We are going to find out what it was hiding! [Response pair appears]. Okay, the tablet was hiding one of these pictures of the [name object]. Which [name object] do you think it was hiding? Go ahead and click it! [Repeat for all 12 sequences]. You did a great job today. I had so much fun!"

Change to Protocol to Minimize Failures: In order to reduce the high criterion task failure rate in Experiment 1, the experimenter added two additional practice criterion sequences before commencing the test sequence. Following, find documentation of the experimenter’s dictation and gestures for the new criterion task.

“Okay, let’s start with a warm-up. [Show criterion warm-up card with two views of couch on it]. What is this a picture of? Good job! [Point to the background of the picture, up to the edges of the photograph] And what is this back here? What is over here? [Direct child’s attention to all areas of the photograph]. Great job! These are both pictures of the same couch, but does one picture make the couch look bigger? Which picture makes the couch look bigger? [Give feedback depending on answer].

Great job, let’s try a matching game now. [Show first practice pair]. What is this a picture of? You’re right! [Use finger to draw attention to background of photograph up to the edges]. What is over here? What about over here? Good! Which
one of the pictures makes this [name object] look bigger? Which one looks smaller?
[Flip over practice criterion target picture] Now, can you tell me which of these [name objects in picture, indicating images on response card with finger] is the same size as this [point to target photograph, name object]? [Use finger to slide target photograph up and down next to response card, aligning photograph with the top picture and bottom picture on response card so that participant can see them side by side while trying to match images based on size]. [Provide feedback based on answer]. Let’s try another. [Repeat for second criterion practice, then repeat for 6 test trials without giving feedback on answers and discussing which object looks larger or smaller before asking child to match pictures based on size].
Appendix B
COUNTERBALANCING CHARTS

Table 1  Experiment 1 Counterbalancing Chart

<table>
<thead>
<tr>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>Group D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Order:</strong> All participants view stimulus Set A during Session 1 and stimulus Set B during Session 2.</td>
<td><strong>Order:</strong> All participants view stimulus Set A during Session 1 and stimulus Set B during Session 2.</td>
<td><strong>Order:</strong> All participants view stimulus Set B during Session 1 and stimulus Set A during Session 2.</td>
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</tr>
<tr>
<td><strong>Close vs Wide Scenes:</strong> Half of the photos in each set are close-up targets—the close-up targets and wide-angle targets are the same photos here as in Group C. Children in Group A and Group C see the same exact photos, just in a different order.</td>
<td><strong>Close vs Wide Scenes:</strong> Half of the photos in each set are close-up targets—the close-up and wide-angle targets are the same photos here as in Group D. The children in Group B and Group D see the same exact photos, just in a different order.</td>
<td><strong>Close vs Wide Scenes:</strong> Half of the photos in each set are close-up targets—the close-up and wide-angle targets are the same photos here as in Group A. Children in Group C and Group A see the same exact photos, just in a different order.</td>
<td><strong>Close vs Wide Scenes:</strong> Half of the photos in each set are close-up targets—the close-up and wide-angle targets are the same photos here as in Group B. The children in Group D and Group B see the same exact photos, just in a different order.</td>
</tr>
<tr>
<td><strong>Order of Presentation:</strong> Half of the children complete a card session first, and half complete a tablet session first.</td>
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</tr>
<tr>
<td>Tablet First</td>
<td>Cards First</td>
<td>Tablet First</td>
<td>Cards First</td>
</tr>
<tr>
<td>Females: 1</td>
<td>Females: 2</td>
<td>Females: 1</td>
<td>Females: 2</td>
</tr>
<tr>
<td>Males: 2</td>
<td>Males: 1</td>
<td>Males: 1</td>
<td>Males: 2</td>
</tr>
<tr>
<td>Mean age: 4.49</td>
<td>Mean age: 4.61</td>
<td>Mean age: 4.58</td>
<td>Mean age: 4.43</td>
</tr>
</tbody>
</table>
Table 2 Experiments 2 and 3 Counterbalancing Table. Because some children only passed one criterion task and were therefore included in only one of Experiment 2 or Experiment 3, children who only completed Experiment 2 are indicated by red font and children who only completed Experiment 3 are indicated by blue font. Information for number of males and females included is listed such that the first number indicates how many children in that group completed both experiments, and the second colored number indicates how many children in that group completed only the experiment that corresponds with the color.

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<tr>
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</tr>
<tr>
<td><strong>Order of Presentation:</strong> Half of the children complete Experiment 2 first, and half complete Experiment 3 first.</td>
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<td>Females: 2</td>
<td>Males: 1</td>
</tr>
<tr>
<td>Males: 1</td>
<td>Males: 1</td>
<td>Males: 0</td>
<td>Males: 1</td>
</tr>
<tr>
<td><strong>Mean age:</strong> 4.36</td>
<td><strong>Mean age:</strong> 4.47</td>
<td><strong>Mean age:</strong> 4.44</td>
<td><strong>Mean age:</strong> 4.44</td>
</tr>
</tbody>
</table>