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Learning from Apps and Objects: The Human Touch

Sierra Eisen[1] and Angeline S. Lillard[1]

ABSTRACT— In three studies, we examined children's geography learning from a physical puzzle and an app designed to mimic the puzzle. In Study 1, 5- and 6-year-olds were taught Australia's states by an experimenter using a puzzle or were taught by an app. Children learned significantly more states from instruction with the puzzle than when they used the app independently. When children were allowed to bring home the puzzle or app for 1 week in Study 2, total learning between conditions was comparable. Length and frequency of use were related to learning only for puzzle users. In Study 3, children were taught the geography lesson by an experimenter using the app. Children's learning from this social app condition was equal to the social puzzle condition but higher than the solo app condition of the earlier studies, suggesting that learning from digital devices is most successful when supplemented with in-person social interaction.

The rise of touchscreen technology has transformed children's media use, making it more flexible and interactive through applications (apps) that respond contingently, in comparison to traditional media like television (Christakis, 2014). Consequently, many apps are designed to teach children: More than 80% of the top-selling apps in the Education category of the Apple App Store are aimed at children (Shuler, 2012). Research on the educational impact of touchscreens is forthcoming, informed by learning from videos and electronic books.

Learning from Videos and E-Books

Learning is often framed as the ability to transfer knowledge between contexts (Barnett & Ceci, 2002). Young children often fail to transfer information from television to the real world (e.g., Anderson & Pempek, 2005; Barr & Hayne, 1999; DeLoache et al., 2010), a problem originally referred to as the *video deficit* but now as a *transfer deficit* since similar limitations apply to children's learning from touchscreens (Moser et al., 2015; Zack, Barr, Gerhardstein, Dickerson, & Meltzoff, 2009; Zack, Gerhardstein, Meltzoff, & Barr, 2013). Socially contingent interactions confer better learning (DeLoache et al., 2010; Roseberry, Hirsh-Pasek, Parish-Morris, & Golinkoff, 2009): Toddlers were three times more likely to find a hidden object if a live person explained its location compared to a person on video (Troseth, Saylor, & Archer, 2006). But, if the person on video interacted with them, children's performance improved dramatically. Children under 3 years seem to need live, in-person interaction to facilitate learning from video, whereas older children can do so on their own (Roseberry et al., 2009). Yet, social interaction does not always enhance children's learning; sometimes, it may distract children by drawing attention to the social partner rather than the content (Nussenbaum & Amso, 2016).

Families frequently read or watch television together, but less often co-use tablets and smartphones (Connell, Lauricella, & Wartella, 2015). When they do, interactions can suffer; parents and children talk less overall or use less varied speech (i.e., unique words) while playing with electronic toys versus traditional toys and books (Sosa, 2016; Zosh et al., 2015). Conversation during e-book reading often focuses more on the device than the story, hurting children's story comprehension (Chiong, Ree, Takeuchi, & Erickson, 2012; Krcmar & Cingel, 2014; Parish-Morris, Mahajan, Hirsh-Pasek, Golinkoff, & Collins, 2013). However, some have found that e-books increase engagement, resulting in equal story comprehension from digital and physical books (Lauricella, Barr, & Calvert, 2014) or even an advantage (Strouse & Ganea, 2017). A meta-analysis found a similar impact on children's story comprehension from e-books and traditional stories, but only if the traditional story was read with an adult (Takacs, Swart, & Bus, 2014).

Learning from Electronic Devices

Children under 3 years have difficulty transferring learned information between touchscreens and three-dimensional

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objects (Moser et al., 2015; Zack et al., 2009, 2013), but older children fare better. First graders' math achievement improved after using a math app for 6 months (Berkowitz et al., 2015), and 4- to 6-year-olds, but not 3-year-olds, learned to solve the Tower of Hanoi equally well from physical or digital exposure and transfer bi-directionally (Huber et al., 2016; Tarasuik, Demaria, & Kaufman, 2017). Additionally children who were taught novel animal facts by an experimenter or an app with a talking cartoon llama learned equally well (Kwok et al., 2016). For specific skills like telling time or measuring, preschoolers successfully learn from touchscreens (Aladé, Lauricella, Beaudoin-Ryan, & Wartella, 2016; Wang, Xie, Wang, Hao, & An, 2016), but it is unclear whether they would learn just as much from using physical objects.

Social interaction appears key. Children often lead, with parental support, when using apps compared to physical books and toys (Griffith & Arnold, 2019). Parent support can be physical/technical (e.g., touching the screen for the child), verbal/cognitive (e.g., providing directions), and emotional/affective (e.g., giving praise; Neumann, 2018; Wood et al., 2016). When parents provide content-related support, children's content knowledge and device skills improve (Flynn & Richert, 2015), and maternal scaffolding helps infants transfer between touchscreens and real objects (Zack & Barr, 2016). Even minimal interaction can facilitate learning. Zimmermann, Moser, Lee, Gerhardstein, and Barr (2017) showed 2.5 and 3-year-olds how to put together a three-piece puzzle on a touchscreen and tested transfer to another touchscreen. If the puzzle pieces moved independently, children did not transfer; if an experimenter silently moved the pieces, transfer improved.

The Present Study

Important questions remain about how learning differs when content is presented in physical and digital formats, particularly when social context is manipulated. In three studies, we compared experimenter-provided instruction using a physical puzzle of a map of Australia to instruction provided by an app version of the puzzle and assessed children's learning. The puzzle and its lesson are part of the Montessori education curriculum for 3- to 6-year-old geography instruction. The app was built by TenSun Interactive, an educational media company, to closely match the puzzle's design and curriculum, allowing direct comparison.

In Study 1, we compared children's learning after a 10-min lesson with a puzzle followed by 10 min of free play or 20 min of independent play with the app. In Study 2, children took home the puzzle or the app, and we tested learning after 1 week. In Studies 1 and 2, children used the app independently to imitate how they commonly interact with touchscreens (Connell et al., 2015) and to test the assumption that apps alone can educate children. We predicted that children would learn more from a lesson with a physical material than from the app due to social scaffolding. In Study 3, we examined the impact of social interaction by providing a lesson with the app. We predicted that adding a social partner with the app would boost learning.

STUDY 1

Method

Participants

Thirty-two 5-year-olds ($M = 65.10$ months, $SD = 3.81$ months, range = 59–72 months; 16 female) were randomly assigned to either the social puzzle condition ($n = 16$) or the solo app condition ($n = 16$). Five additional children were excluded due to inability to complete the experiment. An a priori power analysis based on pilot data indicated a sample size of 32 to detect a significant effect with 90% power, alpha = .05. Children were predominantly Caucasian and middle class. Participants' parents provided written consent and all children verbally agreed to participate. All studies were approved by the university's Institutional Review Board.

Materials

Children in the social puzzle condition interacted with a nine-piece wooden puzzle (58.5 × 47 cm) representing the six mainland Australian states (Western Australia, the Northern Territory, South Australia, Queensland, New South Wales, and Victoria), one island state (Tasmania), and two neighboring nations (Papua New Guinea and New Zealand), all will be referred to as Australia for simplicity (see Figure 1).

Children in the solo app condition used *iWorldGeography Australia* on an iPad Mini. The digital map image was identical to the puzzle map image. The app had seven activity sections that matched elements of the Montessori lesson, though only sections 1–4 were used: (1) a map of Australia that recited each state as it was pressed; (2) a video where each state was said aloud; (3) a testing section that asked children to identify each state (with feedback); (4) a blank map of Australia onto which puzzle pieces could be moved; (5) a section with written labels of states; (6) a section with the capital of each state; and (7) a section with the flags of Australia, Papua New Guinea, and New Zealand.

Procedure

Learning Phase. The 20-min learning phase occurred in an empty testing room and differed by condition (see Table 1).

Social puzzle condition. The social puzzle lesson was modeled on a Montessori geography lesson. Children were

Fig. 1. Physical (left) and digital (right) puzzles of Australia. Images are not to scale.

Table 1
Differences Between Social Puzzle and Solo App Conditions for Studies 1 and 2

	Puzzle	*App*
Format	Physical	Digital
Size	58.5 × 47 cm	20 × 13.5 cm
Learning phase	10-min lesson and 10-min free play	20-min free play
Test phase	Recognition and recall tested on physical puzzle	Recognition and recall tested on *iWorldGeography* app (section 1)

presented with Australian states in three groups of three, for a total of nine states. The experimenter began by pointing to a state, verbally labeling it, and tracing its shape with a finger. Children were then asked to repeat the state name and trace it with a finger. This process was repeated for each state. After each had been introduced, the experimenter took the three states out of the puzzle and placed them in front of children. The experimenter asked children to hand her a state, place a state in its proper location on the map, or say the state's name. This was repeated for each state in counterbalanced order. Finally, the experimenter held up each piece individually and prompted children to identify it. This process was repeated for all states. After completing all three rounds, which took about 10 min, children engaged in free play with the puzzle for 10 min.

Solo app condition. The solo app condition was designed to mimic the way children often encounter an app—without scaffolding. The experimenter presented the sections of the app, then left children alone to engage in free play with the app. The app sound was turned on throughout the interaction period.

Test Phase. The experimenter tested children's ability to recognize each state and then recall each state's name using the same object on which they learned (but with sound off for the app). For recognition questions, the experimenter asked, "Which one is [state name]?" For recall questions, the experimenter pointed to a state and said, "What is this?" States were asked about in the same random order. Children earned one point for correctly remembering a state's name and half a point for remembering most of its name (e.g., "New Wales" for New South Wales). A second coder coded 25% of both conditions and the intraclass correlation was 1.0.

Results and Discussion

Recognition and recall test scores were highly correlated and summed to create a composite memory score (maximum 18). An independent-samples t test demonstrated that children in the social puzzle condition ($M = 9.28$, $SD = 3.02$, range = 5–16) learned significantly more of Australia's states than children in the solo app condition ($M = 5.22$, $SD = 4.48$, range = 0–18), $t(30) = 3.01$, $p = .005$, Cohen's $d = 1.06$. An experimenter-provided lesson with a puzzle resulted in better learning than a commercial app designed to replace the same material.

STUDY 2

Children in Study 1 had limited exposure to Australia's geography. Although it is impressive that children were able to learn many states in that time, these circumstances might not reflect how children typically learn in their daily lives. Study 2 was designed to replicate Study 1 while also providing more exposure. Children in Study 2 were randomly assigned to either the social puzzle or solo app condition and underwent the same laboratory procedure and test as in Study 1, but then brought home the puzzle or the app for 1 week, after which they returned for a second test. We expected that children would once again learn more from the physical material.

Method

Participants

Thirty-two 5- and 6-year-olds ($M = 66.30$ months, $SD = 5.93$ months, range = 60.5–83.1 months; 14 female) were randomly assigned to either the social puzzle ($n = 16$) or the solo app condition ($n = 16$). Although 6-year-olds were included, the average age was not significantly different from Study 1, $t(62) = -0.97$, $p = .338$. Two additional children were excluded due to experimenter error or inability to complete the study.

Materials

The materials were the same as in Study 1. Children in the social puzzle condition also brought home a 58 × 47 cm laminated map of Australia with each state name labeled to check their work.

Procedure

Children participated in two sessions 7 days apart. Session 1 was identical to Study 1. Session 2 involved a post-test identical to Session 1. A second coder coded 25% of both conditions and the intraclass correlation was 1.0.

Parent Measures. Parents recorded when and for how long their children played with the material and rated their engagement from unengaged (1) to very engaged (5). Children freely chose whether to use the material and were not directly encouraged.

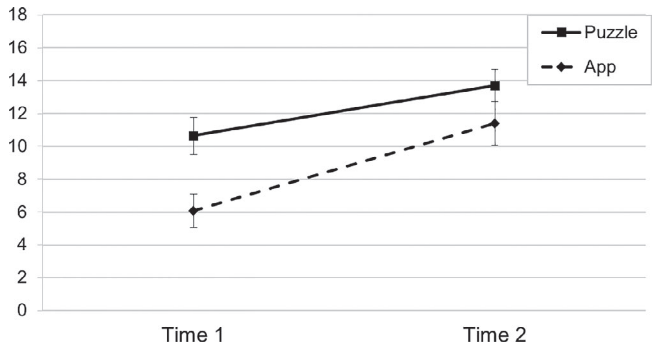

Fig. 2. Mean number of states remembered (combining recognition and recall) for each time point of Study 2.

Results and Discussion

Children's memory scores in the social puzzle condition were significantly higher at Time 1 ($M = 10.63$, $SD = 4.52$, range = 4.5–18) than children in the solo app condition ($M = 6.06$, $SD = 4.12$, range = 1–16), $t(30) = 2.98$, $p = .006$, $d = 1.06$. However, the difference in learning after 1 week (Time 2) was not statistically significant ($M = 13.71$, $SD = 3.90$, range = 6.5–18 with puzzle; $M = 11.38$, $SD = 5.32$, range = 0–18 with app), $t(30) = 1.42$, $p = .165$, $d = 0.50$ (see Figure 2).

A two-way mixed analysis of variance revealed main effects on memory of both time, $F(1, 30) = 25.85$, $p < .001$, $\eta_p^2 = 0.46$, and condition, $F(1, 30) = 6.46$, $p = .016$, $\eta_p^2 = 0.18$, but no interaction. Post hoc analyses using the Bonferroni adjustment showed that children scored significantly higher at Time 2 ($M = 12.55$, $SE = 0.82$) than Time 1 ($M = 8.34$, $SE = 0.77$), $M_{\text{diff}} = 4.20$, 95% confidence interval (CI) [2.52, 5.89], $p < .001$, suggesting the experience during the intervening week assisted learning in both conditions. The main effect for condition indicated that children in the social puzzle condition ($M = 12.17$, $SE = 0.96$) scored higher overall across the two sessions than children in the solo app condition ($M = 8.72$, $SE = 0.96$), $M_{\text{diff}} = 3.45$, 95% CI [0.68, 6.23], $p = .016$.

Children used the puzzle at home for much less time than the app ($M = 33$ min vs. 79 min, SDs = 32.83, 65.80), $t(29) = 2.44$, $p = .021$, $d = 0.93$. However, children did not differ in the frequency with which they used the puzzle or app ($M = 4.20$ vs. 5.38, SDs = 2.68, 2.39), $t(29) = 1.29$, $p = .207$. Instead, the average interaction time with the app was significantly longer than with the puzzle ($M = 13.62$ min vs. 6.85 min, $SDs = 7.97$, 4.74), $t(29) = 2.85$, $p = .008$, $d = 1.07$; however, parent-rated engagement indicated no significant difference for puzzle ($M = 3.31$, $SD = 0.68$) and app ($M = 3.66$, $SD = 0.89$), $t(29) = 1.22$, $p = .233$, $d = 0.44$.

Correlations examined whether time with each material predicted learning, operationalized as the difference in memory score (Time 2 − Time 1). Total time of use was correlated with learning, $r(29) = .43$, $p = .015$, as was frequency of use, $r(29) = .60$, $p < .001$. These relations held when considering just the social puzzle condition: total time, $r(13) = .74$, $p = .002$; frequency of use, $r(13) = .68$, $p = .006$. The average length of time children used the puzzle in each interaction was also related to learning, $r(13) = .62$, $p = .014$. In contrast, for children who used the app, neither total time nor average length of time with the app was related to learning. Frequency of app use was marginally related to learning, $r(14) = .47$, $p = .064$. Parent-rated engagement was related to learning for the sample as a whole, $r(29) = .48$, $p = .007$, and marginally in the social puzzle condition, $r(13) = .50$, $p = .057$, but not in the solo app condition.

Study 2 replicated the results of Study 1: Children in the social puzzle condition learned significantly more of Australia's states at Time 1 than children in the solo app condition. However, after 1 week of home use, this advantage was reduced; children in the social puzzle and solo app conditions showed comparable knowledge. It is important to note that several children in the social puzzle ($n = 6$) and solo app ($n = 2$) conditions received perfect or almost perfect scores by the second session, suggesting a ceiling effect. Since children in the social puzzle condition scored high at Time 1, it is unclear whether scores at Time 2 reflect limited room for growth with the puzzle or an advantage of learning from the app over time. Yet we found that increased time with the app did not translate into increased learning. Children used the app twice as long as the puzzle but no correlation was found between additional time spent using the app and subsequent learning. Instead, children in the solo app condition learned marginally more if they used the app more frequently. On the other hand, children who used the puzzle benefited from how much time they spent with the puzzle, as well as how frequently they used it. However, small sample sizes limit our interpretation of these correlations.

STUDY 3

Studies 1 and 2 indicate that children learn more from interacting with a puzzle with an experimenter than from interacting with an app alone. However, an intentional confound is that the puzzle involved a 10-min interaction with a real person, whereas the app was limited to the contingency of the touchscreen device. Our aim was to contrast a classic form of teaching to a modern form of teaching, in which children are handed a touchscreen device to learn from on their own. In Study 3, we asked whether preschoolers would learn more from a social app condition, in which they used the app with an experimenter in a lesson adapted from the puzzle condition. We hypothesized that children in the social app condition would outperform children in the solo app condition due to the presence of a social partner.

Method

Participants

Thirty-two 5- and 6-year-olds ($M = 66.16$ months, $SD = 5.38$ months, range = 57.6–76.3 months; 16 female) participated. Four additional children were excluded due to familiarity with the study materials or inability to complete the study. All children participated in a social app condition ($n = 32$) and were compared in analyses to separate children from the social puzzle condition ($n = 32$) and solo app condition (Time 1 only, $n = 32$) from Studies 1 and 2. The age and gender composition of participants did not differ across the three conditions.

Procedure

Study 3's procedure was adapted from the social puzzle condition of Study 1. The sound for the app was turned off during the learning and test phases but was turned on for the free play. The experimenter presented Australia's states in three groups of three using section 1 of the app. The experimenter pointed to a state, verbally labeled it, and traced its shape with a finger. Children were then asked to repeat the state name and trace it with a finger. After each of the three states had been introduced, the experimenter switched the app to section 4, where virtual puzzle pieces of each state could be moved onto the map. The experimenter asked children to point to a state, place a state in its proper location on the map, or say the state's name. Finally, the experimenter returned to section 1 and pointed to each state individually, prompting children to identify the state. This entire process was repeated for all states of Australia. After completing all three rounds within about 10 min, children engaged in free play alone with the app for 10 min. After free play, the experimenter tested children on their recognition and recall using the app as in prior studies.

Results and Discussion

Since children in the social puzzle condition were on average 1.5 months younger than children in the other two conditions, and age was related to learning when comparing across the studies (unlike in the first two studies), age was covaried. A one-way analysis of covariance compared overall memory for Australia's states between the three conditions: social puzzle (Studies 1 and 2, $n = 32$), solo app (Studies 1 and 2, $n = 32$), and social app (Study 3, $n = 32$). There was a significant main effect, indicating a difference in the scores for social puzzle ($M = 9.97$, $SD = 3.81$, range = 4.5–18), app ($M = 5.66$, $SD = 4.25$, range = 0–18), and social app ($M = 12.16$, $SD = 3.74$, range = 4.5–18) conditions, $F(2, 93) = 28.99$, $p < .001$, $\eta_p^2 = 0.39$. Post hoc analyses using the Bonferroni adjustment revealed that children in the solo app condition ($M = 5.41$, $SE = 0.64$; all means adjusted for age) learned significantly less than children in either the social app ($M = 12.06$, $SE = 0.64$), $M_{\text{diff}} = 6.65$, 95% CI [4.44, 8.84], $p < .001$ or the social puzzle condition ($M = 10.31$, $SE = 0.64$), $M_{\text{diff}} = 4.89$, 95% CI [2.67, 7.12], $p < .001$, which were not different from each other, $M_{\text{diff}} = 1.75$, 95% CI [−0.46, 3.96], $p = .170$ (see Figure 3). Children in the social puzzle and social app conditions learned approximately twice as many states than did children who used the app alone. The social puzzle and social app conditions did not differ.

GENERAL DISCUSSION

Study 1 demonstrated that children who received a lesson with a puzzle learned more of Australia's states than children who interacted with an app alone. Study 2 replicated these findings, but after a week using the materials at home, children in both conditions performed comparably. Study 3 revealed that when children received a lesson with the app, they learned more than when they interacted with the app alone, but equal to a lesson with the physical puzzle.

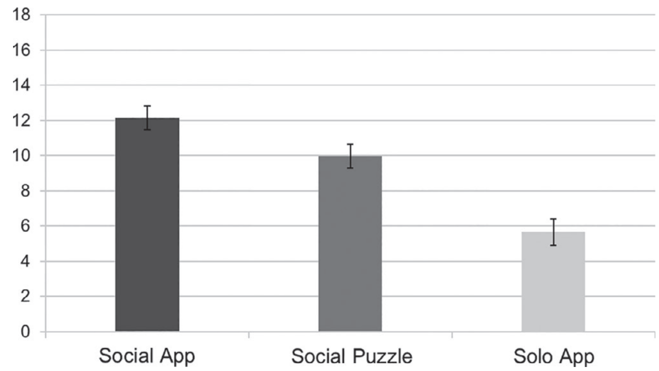

Fig. 3. Mean number of states remembered (combining recognition and recall) in Study 3.

Why did children in the social puzzle and social app conditions learn more than those in the solo app condition? We expect it is because an adult provided *social contingency* in a way the app did not. The app taught children by providing information, testing them, and giving feedback after mistakes, but it could not offer reciprocal communication. A social partner can use referential cues like pointing or gaze direction to attract a child's attention, or convey information through speech. For example, the experimenter in the social puzzle and social app conditions directed the child's attention to the shape of each state by tracing it and invited the child to do the same. Social contingency with a live partner strengthens children's learning from digital media: Toddlers taught novel words through either a live in-person interaction, a live video chat interaction, or a prerecorded video chat learned only from the live conditions (Roseberry, Hirsh-Pasek, & Golinkoff, 2014). Similarly, parents' active involvement while co-reading traditional and e-books improved children's story comprehension (Lauricella et al., 2014). The American Academy of Pediatrics (2016) recommends parents co-use digital media with children, and our research supports this. But since adults are not always available, developers should prioritize designing socially responsive apps.

Conventionally, teachers directly instruct their students. An alternative approach is discovery learning, wherein the learner is not explicitly taught but must instead construct knowledge from provided materials (with or without assistance). A meta-analysis found that direct instruction trumped *unassisted* discovery learning (like free play), but *assisted* discovery learning with guidance from another person surpassed both (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011). This is akin to guided play, during which the adult scaffolds the child's exploration toward a learning goal. Guided play benefits learning by allowing children autonomy while still incorporating adults' knowledge (Weisberg, Hirsh-Pasek, Golinkoff, Kittredge, & Klahr, 2016). A well-designed educational app could work similarly if it guides the activity and provides feedback when needed, as another person might.

We measured learning from only one app and physical material because they allowed for a close comparison of learning tools in which one (the app) was intended to replicate the other (the puzzle). However, apps vary greatly and many are not meant to replicate physical materials, nor could they. Future work should examine a variety of educational apps and focus on the influence of social interactions on children's learning.

CONCLUSION

Our findings highlight the importance of incorporating social interactivity into children's app use. A physical puzzle combined with an adult's lesson resulted in more learning than an app designed to replicate that experience. Yet when an adult gave the lesson using the app, learning improved. Although mobile technology resembles its media predecessors, the novelty of the touchscreen has revolutionized the media landscape. The degree to which learning from apps is like learning from physical materials is practically and theoretically important to education and cognitive development.

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