

**Children’s Vocabulary, Math, and Social-Emotional Learning from Interactive Media: The
Role of Choice, Agency, and Repetition in App Design**

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Abstract

Young children (ages 3-5) can learn from interactive media, but how to best design that media for learning remains unclear. Research with adults more closely examines how the design of media can influence its effects. The Theory of Interactive Media Effects (TIME) model posits that having a choice in content selection can promote feelings of agency, and thus, learning. For children, the amount of content consumed, or repetition of the same content, may also be important factors. In the current study ($N = 31$) three- to five-year-olds played with one of two versions of an app for eight weeks. Children played on a tablet for approximately 15 minutes three times each week ($M = 299$ minutes total). In one version (choice condition), children could choose the games they played on the app, and in the other version (no-choice condition), children were assigned a series of games in a pre-specified order. Children completed vocabulary, math skills, and social-emotional knowledge assessments before and after the intervention. Results demonstrate that children in the choice condition had significant learning gains in all three domains of learning. Children in the no-choice condition only had significant gains in math. Further, for vocabulary and social-emotional knowledge, children's sense of agency was significantly related to learning outcomes, and this was moderated by repetition. The current study demonstrates that the design of children's interactive media can influence feelings of agency and that for children, repetition of content in conjunction with feelings of agency can improve learning outcomes.

Keywords: digital games, interactive media, educational media, TIME model, agency, repetition

Public Significance: The current study was an experiment to see if children learned better from an app when they were able to make their own choices about what games to play. We found that when children felt agentic and played a variety of games, they learned more vocabulary. When children felt agentic and repeated the same games, they learned more social-emotional knowledge.

Children's Vocabulary, Math, and Social-Emotional Learning from Interactive Media: The Role of Choice, Agency, and Repetition in App Design

Children who start kindergarten with a strong background in literacy, numeracy, and social-emotional skills have more academic success and engage more at their schools (Duncan et al., 2007). As preschoolers (ages 3-6) engage with more digital media (Mann et al., 2025), it is important to leverage this media use to support children's well-being. Researchers have demonstrated that children can and do learn skills in literacy, numeracy, and social-emotional learning from media (for review, see Griffith et al., 2020). However, this research has primarily focused on comparing learning from media to learning from physical materials or comparing learning from interactive media to learning from passive media. Further, extant studies typically focus on one domain of learning (such as math) at a time. The current longitudinal experiment with preschoolers (ages 3-5) addresses these gaps in the literature by examining how one app (with many different games) can support learning in vocabulary, math, and social-emotional learning (i.e., theory of mind and emotion recognition) and how this learning can differ based on the design of the app. Extant theory about children's learning from interactive media suggests that interactivity in and of itself should support learning through mimicking social interaction (Aladé et al., 2016), customizing content for children (Mehdipour et al., 2013), or being more engaging than non-interactive media (Kirkorian et al., 2016). Because researchers have not yet examined how differing designs of interactive media may best support children's learning, theory has not yet focused on the finer details of digital game design for children. As such, we consider the Theory of Interactive Media Effects (TIME model; Sundar, Jia, et al., 2015) within the context of supporting children's school readiness. Further, we discuss implications for designing interactive media for young children.

Children's Learning from Interactive Media

Research demonstrates that children, including preschoolers, can learn from interactive media, such as smartphone apps (for review, see Griffith et al., 2020), but there lacks theoretical specificity in the mechanisms that drive this learning. Researchers have borrowed theories of how children learn from television (Choi & Kirkorian, 2016; Kirkorian et al., 2016), how children learn through social interaction (Eisen & Lillard, 2020; Griffith et al., 2022; Lennon et al., 2022), and how experience prompts learning (Aladé et al., 2016; Wang et al., 2016). These theories have illuminated important developmental patterns in children's ability to learn from interactive media, but they have not explained the specific mechanisms by which children learn best from interactive media. Researchers who study adults have more granularly examined how interactivity may influence media effects, including learning.

TIME Model

A key part of communication scholarship is consideration of the medium by which information is transmitted. In other words, medium, just as message, can make a difference in effects. With interactive media, different affordances, or "action possibilities suggested by visual stimuli in [the] environment" (Gibson, 1977, p. 50) can affect how users interact with and experience a message. The TIME model (Sundar, Jia, et al., 2015) proposes pathways from affordances to resulting psychological effects. Two primary pathways are considered: 1.) affordances serving as cues for heuristics and subsequent perception of the source of communication and 2.) affordances prompting action resulting in changes in knowledge, attitudes, and/or behavior. The current study focuses on the second proposed pathway as the outcomes of interest are in knowledge (literacy, numeracy, and emotion knowledge) and behavior (self-regulation). The TIME model suggests that differences in affordances catalyze

cognitive and behavioral change that produce media effects. These pathways will be further explicated in this section, but in essence, the TIME model suggests that varying media designs produce different outcomes. For the current study, we are interested in the presence of choice, which increases feelings of agency (Assor, 2012; van der Kaap-Deeder et al., 2017). The TIME model also includes a mediation pathway from feelings of agency to sense of absorption (or a sense of immersion in media). In this study, we could not successfully measure absorption among young children, but we note it as part of the TIME model's pathways. Agency (and absorption) can then support academic achievement, the main outcome of interest in this study (Okada, 2023). These relations will be explained in this section, but in general, we hypothesize that the design of media will influence learning outcomes such that:

H1: Children in the choice condition will demonstrate greater positive change in their (a) vocabulary, (b) math skills, and (c) social-emotional knowledge than children in the no-choice condition.

One type of affordance considered in the TIME model is an affordance of choice, or the ability to select content. The affordance of having a choice in content should prompt users to make content selections. When users do not have this option, they cannot engage in the action of selection, thus the affordance of choice itself requires different action possibilities (i.e., choosing content or not). These action possibilities then have psychological correlates, such as a sense of agency, defined as the degree to which a user has the control to pursue their own goals and actions (Sundar, Jia, et al., 2015). Research on adults has demonstrated that using interactive media increases feelings of agency (e.g., Jung & Sundar, 2022; Molina & Sundar, 2020), and researchers also suggest that the presence of choice fosters feelings of agency (Assor, 2012; van

der Kaap-Deeder et al., 2017). Aligned with research on interactive media use as well as the TIME model, we hypothesize:

H2: Children in the choice condition will report a greater sense of agency while using the app than children in the no-choice condition.

Part of the TIME model draws from self-determination theory (Deci & Ryan, 2012) which suggests that people can become self-motivated when needs for competence, relatedness, and autonomy (or here, agency) are fulfilled. Self-determination theory emphasizes the importance of agentic motivation in changing behaviors or taking action. Research has demonstrated that agentic motivation is positively associated with learning outcomes among middle schoolers (Basileo et al., 2024). Further, a recent meta-analysis shows that when teachers support agency in the classroom for students, students perform better academically, though effect sizes are small (Okada, 2023). Providing choices in the app can promote feelings of autonomy as children direct their own learning. Based on past research on learning outcomes and autonomy, we predict:

H3: Sense of agency will mediate the relation between condition assignment and change in learning for (a) vocabulary, (b) math skills, and (c) social-emotional knowledge.

Repetition and Learning

While the TIME model considers the type and design of media, it does not consider the dose. An important aspect of learning is repetition. For young children in particular, they can learn more through repeated exposure of the same stimuli in literacy (Horst et al., 2011), math (Fuchs et al., 2010), and social-emotional learning (to a point, Mares, 2006). This effect is also seen in children's learning from media (Crawley et al., 1999; Mares, 2006). As children are still developing their cognitive abilities, including working memory capacity, repetition may be even

more important in learning from interactive media (such as apps) than non-interactive media (like television) because children not only must learn the educational content, they must also master game controls. Past research on preschoolers' learning from interactive media suggests that there may be limitations in learning from it due to these working memory demands (Aladé et al., 2016; Schroeder & Kirkorian, 2016). The Limited Capacity Model for Motivated Media Message Processing has primarily been used for research on adults, but the theory suggests that because humans have a limited capacity to process information, the working memory burden that media places on an individual can produce varying effects (Fisher et al., 2018; Lang, 2000), such as more or less learning from a stimulus. Repeated use of an interactive stimulus may lower the demands placed on working memory, and as such, they may be able to learn more than from a single exposure. Research with adults suggests that repeated exposure to media is motivated by desire for enjoyment, familiarity, and control (for review, see Hoffmann, 2006). Some researchers suggest that repeated exposure can be more relaxing, as it requires fewer cognitive resources (Hoffmann, 2006). Young children are still developing their working memory capacity. As such, they take longer to encode information than older children and adults. Considering self-determination theory (Deci & Ryan, 2012), children's intrinsic motivation may be driven, in part, by a need for competency, which comes through repetition and practice of skills. Many apps for children, including the stimulus in the present study, offer children a variety of mini games within the app. Some apps, including the no-choice version of the stimulus used in our study, select these mini games for children, prescribing a sequence of games each day. Games cannot be repeated, thus there is less opportunity for repetition of the same games within one domain. Children who have choices in their mini games, however, may opt to repeat what is already familiar, using their agency to build greater competency. Thus, we hypothesize:

H4: Repetition will moderate the relation between sense of agency and learning outcomes in (a) vocabulary, (b) math, and (c) social emotional knowledge such that greater repetition will strengthen the positive relation between agency and learning outcomes.

The current study thus contributes to the literature on interactive media effects by considering more closely how the dosage of an educational message (in our case, educational content in games) influences learning outcomes. Preschoolers value repetition, and thus when given options, they may choose to repeat the same content rather than exploring new content when they have the agency to do so. Taking advantage of this aspect of development when designing games for children can optimize educational outcomes.

Method

The current study examines how the affordance of choice affects learning outcomes as mediated by sense of agency and absorption with two different, commercially available versions of the app *Lingokids*. These versions were acquired directly from the company. One (choice version) is their paid version of the app while the other (no-choice) is the free version. None of the participants paid for the app as it was provided to them for free by the research team. Three- to five-year-olds participated in an eight-week longitudinal intervention in which they used one version of the app (no-choice or choice) for 15 minutes/day three times each week.

Participants

Children ($N = 31$)¹ in three classrooms at a local preschool near a public West Coast university participated in the study: 45.16% identified as White ($n = 14$), 12.90% as Hispanic or

¹ The preschool we worked with initially had 82 eligible children for the study based on their enrollment numbers online. Because of changes to curricular approach, around 48 children were eligible for the study by the time we started recruitment. The researchers also note difficulty in obtaining parent consent for this study due to parents' aversion to use of technology in the classroom. Post-hoc, we conducted six power analyses to determine how certain

Latino ($n = 4$), 22.58% as Asian ($n = 7$), and 19.35% as two or more races ($n = 6$). The sample was composed of 29.03% boys, ($n = 9$) and 67.74% girls ($n = 21$), and 3.23% nonbinary children ($n = 1$). The mean age of the children was 3.97 years ($SD = 0.71$). The median education level for parents was an undergraduate degree, and the median household income fell between \$75,000 and \$99,999. See Table 1 for a full zero-order correlation table.

The three classrooms with children in the age group of interest participated in the study. A breakdown of participant demographics by classroom and condition assignment can be found in the Supplemental Materials. Eighteen children across two classrooms (7 in one half-day classroom and 11 in the other full-day classroom) participated in the choice condition, and 13 children in one classroom participated in the no-choice condition. Classrooms were randomly assigned in a sequential order to avoid the potential for 24 children to be in one condition with only 7 in the other. All classroom teachers, who were of similar educational background and age, were blind to the study design and purpose. The preschool itself is play-based and project-based which means children learn through experience rather than specific lessons or lecture. As such, children should not have differed significantly in terms of exposure to our outcome variables of interest over the course of the eight weeks.

Materials

Materials included two versions of the educational app *Lingokids*, which targets school readiness skills in literacy, numeracy, and social-emotional learning. Both versions of the app consist of a variety of games, such as a game where children complete simple addition problems to move ahead in a swimming race and a game where children use a magic wand to practice

we can be in detecting our results, especially as compared to other studies in this field. We are well-powered (99.99%) to detect large effects in our data, but we are underpowered in detecting small effects. See Supplemental Materials for details.

writing letters. In one version of the app (no-choice condition), *Lingokids* provides a curated curriculum that children must follow. In this version, children can only play one game at a time, and they cannot go back and repeat games that they have already played that day. In the other version (choice condition), children can access all games as desired, and they can repeat games. Children in the study were provided with personal Amazon Fire Kids tablets to play with the app. *Lingokids* was the only activity available on the tablets. Children kept the tablets when the study was complete, but during the 8-week intervention, they were not able to download additional games, and the tablets remained in the classroom until the end of the study.

Procedure

The procedure was approved by the relevant Institutional Review Board. Children completed pre-test measures in vocabulary, math, and social-emotional knowledge before random condition assignment by classroom. Classroom teachers were told that children should play with the app three times each week for 15 minutes each session on their personal tablets, and children in both conditions played for similar amounts of time, as demonstrated through back-end data from *Lingokids* that recorded minutes of engagement. After eight weeks of engagement with the app, children completed post-test measures in vocabulary, math, and social-emotional knowledge. Children also answered questions about their sense of agency while using the app.

Measures

Vocabulary

The Peabody Picture Vocabulary Test was used to assess receptive vocabulary (Dunn & Dunn, 1965). We used all of items 22-76, which are the items indicated for 4-8-year-olds. We used this small subset of some of the four-year-old and eight-year-old words to not fatigue the

children. Children heard a word (such as “castle” or “picking”) and pointed to one of four pictures that appeared in front of them. The number of correct items out of a potential 55 were summed, and scores from Time 1 ($M = 46.45$, $SD = 8.43$) were subtracted from scores from Time 2 ($M = 49.45$, $SD = 5.73$) to create a change score ($M = 3.00$, $SD = 5.19$). Thus, a positive score indicates a gain in vocabulary.

Math

Math skills were assessed through part of the Mathematical School Readiness test (Mejias et al., 2019) as well as through a unit counting task (Sarnecka & Carey, 2008). Children first completed a *number identification* task in which they saw Arabic numerals (e.g., 3, 6, 8, 9) alongside non-numeric symbols (e.g., a, @, \$, f). Children were asked to circle numerals and cross out non-numerals. The number of correct responses were summed for a maximum score of 8. Children then completed a *number comparison* task in which they saw 12 pairs of numbers and pointed to the number that they thought was the larger of the two. Numbers ranged from 2 to 420. Correct answers were summed with a maximum score of 12. Children also engaged in a *unit counting* task. A researcher had four sets of identical objects (stars, baseballs, rubber ducks, and checkers) that she would place into a bowl in front of the child. For example, she might say “I am placing FOUR ducks into the bowl” and then cover the bowl with a lid. She would then check the child’s memory by asking “how many ducks are in the bowl?” If the child answered incorrectly, she would tell them to try again and start the task over. If the child answered correctly, she would continue the task saying “now watch” and add either one or two more of the same item(s) in the view of the child. Then she would ask the test question by asking if the number of items was $N + 1$ or $N + 2$ (e.g., “Now is it FIVE or SIX?”). Children did not receive feedback after the trials. Correct responses were summed for a maximum score of six. The scores

of all tasks were summed and the score from Time 1 ($M = 17.13$, $SD = 3.52$) was subtracted from the score at Time 2 ($M = 19.03$, $SD = 3.79$) to create a change score ($M = 1.90$, $SD = 2.53$). Thus, a positive score indicates a gain in math.

Social-Emotional Knowledge

Social-emotional knowledge was assessed with an emotion recognition task as well as theory of mind questions (Rasmussen et al., 2019).

Emotion Recognition. Children saw four photographs of an adult woman and four cartoon drawings of a person who was supposed to look like the same gender as the child (all images identified by the name “Pat”).² Each image depicted a happy, sad, angry, or fearful expression. Children were asked to identify the emotion felt by the person in the image. Answers were recorded verbatim and coded as correct or incorrect based on the emotion and valence (positive or negative) identified in their response. Two points were assigned to answers identifying correct emotion and valence, one point to answers identifying the correct valence only, and zero points for an incorrect response. One item was excluded from analysis (the photograph depicting “scared”) as many children identified the expression as “surprised” rather than “afraid” and when we asked adults, they also were not sure whether she was surprised or afraid. Correct responses were summed for a maximum score of 14.

Theory of Mind. After identifying emotions in the drawings, children were told seven scenarios about the character Pat (gender-matched to the child). A researcher told children that in each short scenario, Pat might feel happy, sad, angry, or scared. The researcher pointed to each of the appropriate drawings to show the child the emotions. Then researchers read each scenario

² For the one non-binary child in the sample, we used “they/them” pronouns for Pat to match the pronouns of the child. We used the drawing of Pat that most resembled the participant’s appearance along with the appropriate pronouns.

(e.g., “How would Pat feel if he/she/they got a new bike?”) and asked the child how Pat would feel. Like the emotion recognition task, answers were recorded verbatim and coded as correct or incorrect based on the emotion and valence (positive or negative) identified in their response. Two points were assigned to answers stating correct emotion and valence, one point to answers with the correct valence only, and zero points for an incorrect response. Correct responses were summed for a maximum score of 14.

Scores from both tasks were summed to create a social-emotional knowledge score, and scores from Time 1 ($M = 20.00$, $SD = 6.56$) were subtracted from scores from Time 2 ($M = 22.61$, $SD = 3.89$) to create a change score ($M = 2.70$, $SD = 4.80$). Thus, a positive score indicates a gain in social-emotional knowledge.

Sense of Agency

Before starting post-testing, children responded to questions about sense of agency while using the app. No measure of this construct has been developed for this age group with regard to interactive media use, thus we adapted a measure used in a study of adults (Sundar, Go, et al., 2015) with seven statements such as “I can make choices freely on *Lingokids*” and “I felt in charge while playing *Lingokids*.” The measure was constructed in consultation with the preschool director to ensure the children would understand the language used. Children were asked each question as “yes” or “no” and then they were asked to specify whether they felt that way “a little” or “a lot.” Answers for “no” corresponded to scores of 1 (“a lot”) and 2 (“a little”), and answers for “yes” corresponded to 3 (“a little”) and 4 (“a lot”). Items were averaged ($M = 3.25$, $SD = 0.77$).

App Use Data

Children's app use data was collected and provided to researchers by the company. Data include which games were selected, how many times each game was played, if the game was completed, and for how long each game was played. *Repetition rate* ($M = 1.86$, $SD = 0.43$) was calculated by dividing the number of times a child repeated any game over the number of unique games the child played in all. For example, if a child played 100 unique games and played one game 10 times and another game 5 times, their repetition rate would be $15/100$ or 0.15 . It is important to note that repetition was not "0" by default for children in the no-choice condition. The app provided a set list of games each day for children in this condition, and sometimes the same game could appear on different days, making the repetition rate for that game greater than 0. Further, the *total time played* over the course of eight weeks was reported ($M = 299.62$ minutes, $SD = 95.17$ minutes). The *completion rate* or the proportion of games played through to completion was also calculated ($M = 0.60$, $SD = 0.14$).

Results

Because children were randomly assigned by classroom, rather than individually, to each condition, we looked for significant correlations with potential covariates and condition assignment. See Table 1 for a full zero-order correlations table. Children assigned to the no-choice condition were significantly older than children in the choice condition. Further, children assigned to the no-choice condition scored higher at pre-test on number identification and vocabulary. Because of these significant differences, we ran separate paired t-tests to compare children's scores at Time 1 and Time 2 for each condition. A direct comparison between conditions was made with ANOVA to assess time played, completion rate, repetition rate, and sense of agency.

To test the relationship between condition and children's sense of agency (H1), the impact of the condition on learning gains across vocabulary, math skills, and social-emotional knowledge (H2), the influence of agency on learning gains in these domains (H3), and the moderating role of repetition on the relationship between agency and learning outcomes (H4), we used PROCESS Model 14 (Hayes, 2017). See Figures 1 and 2 for visual summaries of results.

ANOVA Results

Time, Completion, and Repetition

Children in both the choice ($M = 299$ minutes, $SD = 122$) and no-choice ($M = 301$ minutes, $SD = 44.60$) conditions played with the app for similar amounts of time over the eight weeks ($F(1,28) = 0.005$, $p = .95$), and children in the choice ($M = 0.56$, $SD = 0.14$) and no-choice ($M = 0.65$, $SD = 0.14$) conditions had similar rates of game completion ($F(1,26) = 3.31$, $p = .08$). However, children in the choice condition ($M = 2.07$, $SD = 0.46$) repeated games more frequently than children in the no choice condition ($M = 1.59$, $SD = 0.17$; ($F(1,26) = 11.95$, $p = .002$).

Sense of Agency

Children in the choice condition reported a stronger sense of agency related to the app ($M = 3.52$ on a 4-point scale, $SD = 0.55$) as compared to children in the no-choice condition ($M = 2.89$, $SD = 0.90$, $F(1,28) = 5.65$, $p = .02$).

Paired t-test Results

Vocabulary

Paired sample t-tests demonstrated that there was a significant change in vocabulary scores ($\Delta M = 4.17$ new words; $SD = 5.26$) for children in the choice condition ($t(17) = -3.36$, $p = .004$) while there was not a significant change for children in the no-choice condition ($\Delta M = 1.38$ new words; $SD = 4.82$; $t(12) = -1.04$, $p = .32$).

Math

Paired sample t-tests demonstrated that children in both the choice ($\Delta M = 1.89$, $SD = 2.74$; $t(17) = -2.92$, $p = .009$) and no choice ($\Delta M = 1.92$, $SD = 2.33$; $t(12) = -2.98$, $p = .01$) conditions had significantly higher math scores at Time 2 than at Time 1.

Social-Emotional Knowledge

Paired sample t-tests demonstrated that there was a significant change in social-emotional knowledge scores for children in the choice condition ($\Delta M = 3.59$ more questions correct after intervention; $SD = 5.41$; $t(16) = -2.74$, $p = .01$) while there was not a significant change for children in the no-choice condition ($\Delta M = 1.54$; $SD = 3.76$; $t(12) = -1.48$, $p = .17$).

Vocabulary Learning Gains

We used PROCESS Model 14 (Hayes, 2017) to examine the relationship between condition and agency, the effect of condition and sense of agency on vocabulary learning gains, and the moderating role of repetition in the relationship between agency and vocabulary learning outcomes. Notably, the distribution of change in vocabulary scores did not pass tests of normality, and thus we used bootstrapping with 5,000 resamples to be robust against this normality assumption violation.

The overall model was significant, $R = 0.59$, $R^2 = 0.34$, $F(4,22) = 2.89$, $p = .046$. There was not a direct significant relation of condition on vocabulary learning gains ($\beta = -0.19$, $SE = 0.41$, $p = .647$, 95% CI [-1.03, 0.66]); thus, H1a was not supported. Results indicated that participant condition significantly predicted sense of agency ($\beta = 0.94$, $SE = 0.35$, $p = .013$, 95% CI [0.22, 1.67]), such that sense of agency was higher among children in the choice condition compared to the no-choice condition, supporting H2. The direct relation of sense of agency on vocabulary learning gains was not significant ($\beta = -0.001$, $SE = 0.17$, $p = .995$, 95% CI [-0.35,

0.35]). The indirect effects of condition on vocabulary learning gains, as mediated by sense of agency was not significant at all three levels of repetition: low (-1 SD ; $\beta = 0.29$, 95% CI $[-0.02, 1.01]$), medium [$\beta = 0.12$, 95% CI $[-0.16, 0.69]$], and high [$\beta = -0.57$, 95% CI $[-1.46, 0.55]$], not supporting H3a. Lastly, repetition significantly moderated the relationship between agency and vocabulary learning gains ($\beta = -0.37$, $SE = 0.17$, $p = .041$, 95% CI $[-0.73, -0.02]$), supporting H4a. We examined the conditional effects of agency on vocabulary learning gains at varying levels of repetition. At low (-1 SD) levels of repetition, agency had no significant effect on vocabulary learning gains ($\beta = 0.31$, $SE = 0.21$, $p = .153$, 95% CI $[-0.12, 0.74]$). Similarly, at mean levels of repetition, the effect remained nonsignificant ($\beta = 0.12$, $SE = 0.17$, $p = .481$, 95% CI $[-0.24, 0.48]$). Even at high levels of repetition ($W = +1\text{ SD}$), agency failed to produce a significant effect on vocabulary learning outcomes ($\beta = -0.6$, $SE = 0.34$, $p = .092$, 95% CI $[-1.31, 0.11]$). Because these results were null, we followed these analyses with a Johnson-Neyman test to determine at what level of repetition the significant effect emerged. The test demonstrated that the effect of agency on vocabulary gains was significant ($p < .05$) when repetition rate falls outside the theoretical interval $[0.91, 3.83]$. Both values of this region are outside the minimum and maximum levels observed in the dataset, but in the regions of significance, learning is highest when repetition rates are outside the lower bound of the interval (below 0.91) and lowest when repetition rates are outside of the upper bound (above 3.83); thus repetition interacts with agency to produce vocabulary learning at low levels of repetition.

Math Learning Gains

The distribution of math score change was normal, but we still used 5,000 resamples for bootstrapping in the model to be consistent with other models. The overall model was not significant, $R = 0.22$, $R^2 = 0.05$, $F(4,22) = 0.28$, $p = 0.888$. There was not a significant direct

relation from condition to math learning gains ($\beta = 0.07$, $SE = 0.57$, $p = 0.898$, 95% CI [-1.11, 1.25]), not supporting H1b. There was a significant relation between participant condition and feelings of agency ($\beta = 0.94$, $SE = 0.35$, $p = .013$, 95% CI [0.22, 1.67]), supporting H2. The indirect effects of condition on math learning gains, as mediated by sense of agency was not significant at all three levels of repetition: low ($\beta = 0.16$, 95% CI [-0.40, 0.87], medium [$\beta = 0.08$, 95% CI [-0.55, 0.62], and high [$\beta = -0.21$, 95% CI [-2.57, 1.01], not supporting H3b. The relation between sense of agency and math learning gains was not significant ($\beta = 0.06$, $SE = 0.24$, $p = .812$, 95% CI [-0.44, 0.55]). Repetition also did not significantly moderate the relationship between agency and math learning ($\beta = -0.12$, $SE = 0.24$, $p = .618$, 95% CI [-0.62, 0.38]), not supporting H4b.

Social-Emotional Knowledge Learning Gains

The distribution of social-emotional knowledge score change was normal, but we still used 5,000 resamples for bootstrapping in the model for consistency. The overall model was not significant, $R = 0.59$, $R^2 = 0.35$, $F(4,21) = 2.78$, $p = .054$. There was no direct significant relation from condition to social-emotional learning gains ($\beta = 0.47$, $SE = 0.48$, $p = 0.34$, 95% CI [-0.53, 1.48]), not supporting H1c. Results indicated that participant condition significantly predicted feelings of agency ($\beta = 0.90$, $SE = 0.27$, $p = 0.02$, 95% CI [0.16, 1.65]), supporting H2. There was also not a significant relation between agency and social-emotional learning gains ($\beta = 0.30$, $SE = 0.20$, $p = .144$, 95% CI [-0.11, 0.71]). The indirect effects of condition on social-emotional knowledge gains, as mediated by sense of agency was not significant at all three levels of repetition: low ($\beta = 0.35$, 95% CI [-0.02, 1.18], medium [$\beta = 0.16$, 95% CI [-0.17, 0.84], and high [$\beta = -0.58$, 95% CI [-1.74, 0.73], not supporting H3c. However, repetition did significantly moderate the relation between agency and social-emotional learning gains ($\beta = 0.50$, $SE = 0.20$, p

= .021, 95% CI [0.08, 0.92]), supporting H4c. The conditional effects of agency on social-emotional learning gains were examined at varying levels of repetition. At low (-1 SD) levels of repetition, agency had no significant effect on social-emotional learning gains ($\beta = -0.13$, $SE = 0.24$, $p = .611$, 95% CI [-0.63, 0.38]). At mean levels of repetition, agency did not have a significant effect on social-emotional learning outcomes ($\beta = 0.13$, $SE = 0.20$, $p = .535$, 95% CI [-0.29, 0.55]). Agency had a significant effect on social-emotional learning outcomes at high (+1 SD) levels of repetition ($\beta = 1.11$, $SE = 0.40$, $p = .012$, 95% CI [0.27, 1.95]).

Discussion

The current study tested how having choice of game within an app influenced young children's (ages 3-5) learning over an eight-week period. Children played with the app *Lingokids* three times each week for eight weeks and either had free choice in selecting games or were assigned a series of games to play during each session. Children were assessed before and after the intervention in three domains of learning: vocabulary, math, and social-emotional knowledge. Children in the choice condition reported a stronger sense of agency while playing the game, which is consistent with the hypotheses of the TIME model (Sundar, Jia, et al., 2015). For vocabulary and social-emotional learning outcomes, repetition significantly moderated the relation between agency and learning. For social-emotional learning, children who felt more agentic and repeated games more also learned more, but for vocabulary, we found that lower levels of repetition interact with sense of agency to produce greater learning outcomes. The finding for vocabulary can perhaps be explained by the number of unique vocabulary games children played on average as compared to math and social-emotional games. For vocabulary learning, children who explored more vocabulary games also spent more time with vocabulary games. There is a significant and positive correlation between the total number of unique

vocabulary games played and time spent playing vocabulary games in general. Past research supports the idea that more exposure to novel words leads to increased vocabulary skills (Huttenlocher et al., 1991), and thus the time spent with vocabulary games generally may have been more important than simply reinforcing the same words repeatedly. These same relations did not hold for math learning, however. Paired t-tests also revealed that children in the choice condition had significantly greater scores in vocabulary and social-emotional knowledge after the intervention than before while children in the no-choice condition did not. Children in both conditions had significantly higher math scores after the intervention than before. The current study demonstrates the utility of the TIME model with child populations and the inclusion of repetition (i.e., dosage) as a moderating variable in the model. Further, our results point to the importance of app design on sense of agency in supporting children's learning.

Theoretical Implications

The current study tested the TIME model with young children (ages 3-6) and added in an element of repetition as a moderating variable. One part of the TIME model incorporates self-determination theory (Deci & Ryan, 2012), which suggests that competence, relatedness, and agency drive behavior. Here we examined how agency and the development of competence (repetition) interact to produce learning outcomes. While children are a special population of interest and have different susceptibilities to media effects than adults, they also share characteristics and needs with adults, such as those identified in self-determination theory. One difference between children and adults, however, may be how children develop competence. Research with adults (Goode et al., 2008) suggests that variable practice (rather than repetitive practice) can lead to greater learning outcomes. In our study, children in the choice condition played games for the same amount of time and had similar completion rates of games as children

in the no-choice condition, but they felt more agency and repeated games more often. Repetition, coupled with a sense of agency, was associated with greater learning outcomes in vocabulary and social-emotional learning. Thus, it is possible that children build competency in ways different from adults when using interactive media.

Our results demonstrate preliminary evidence for further considering developmental susceptibilities within the TIME model. As noted in our literature review, young children are still developing their working memory capacity, and they take longer to encode information than adults and adolescents. We consider self-determination theory (Deci & Ryan, 2012) and how children's intrinsic motivation may be driven by a need for competency, as produced by repetition and practice. There is support for this idea in our findings about the interaction of sense of agency and repetition for social-emotional skills, but we found the opposite for vocabulary skills. The lowest levels of repetition moderate the relation between agency and vocabulary learning gains. Research should more closely consider how different domains of learning (here, vocabulary, math, and social-emotional knowledge) are strengthened, as these domains are often assessed separately (Griffith et al., 2020). While research supports the idea of repeated practice for building vocabulary skills from reading books (Therrien, 2004), it is possible that children benefit from varied practice when playing digital games. This idea can be empirically tested. Most importantly, children's limited working memory capacity should be considered when testing the design of educational media for children. In our study, children were able to use the stimulus over the course of eight weeks, thus having time to become familiar with the game controls. Including repetition as a moderating variable in the TIME model can help account for this developmental susceptibility.

Practical Implications

Implications for Research

Researchers studying children's use of interactive media should more closely consider how the design of these media can influence children's learning outcomes. Often research compares interactive media to non-interactive media (e.g., Aladé et al., 2016) or looks at how one design of a pre-existing app may or may not produce learning (e.g., Lennon et al., 2022). This study is unique in longitudinally testing the same app with slightly modified designs. Our results demonstrate that designing the app to give children choice influenced children's feelings about using the app, their actual use of the app (repetition rate), and, in turn, their learning outcomes. As noted above, children share some characteristics with adults, but they may express or fulfill these needs in different ways. Communication research on interactive media design has mostly been with adult populations, but children and media scholars can build from this work by using theoretical understandings primarily tested with adults (such as the TIME model) and incorporating developmental understandings to better design media for young children.

Implications for Practice

While interactive media are readily available to young children (Rideout & Robb, 2020), the design of these media (beyond the educational content itself) is not often considered. Children, like all humans, have a need for agency (Deci & Ryan, 2012), and building opportunities for agency into their interactive media can help foster learning, as demonstrated in the current study. Further, our results demonstrate that when children do have the ability to make independent choices within an app, they choose to repeat familiar games, which increases their competence in these activities. Many apps for children, including the no-choice version of *Lingokids*, give children a preset list of activities that they must follow. While children can learn

from this method, as demonstrated in past research (Griffith et al., 2022), it is clear that providing opportunities for agency, like choosing a game, can lead to greater learning outcomes. Game designers should more closely consider how to incorporate these opportunities into their apps, and parents should look for apps that have such features.

Strengths, Limitations, and Future Directions

Strengths of this study include a longitudinal design as well as the assessment of multiple domains of learning. Though other researchers have used longitudinal studies to address children's learning from interactive media over time (for review, see Griffith et al., 2020), only one study has examined design features that may influence this learning (Au & Leung, 1991). This study focused on the classroom instruction surrounding the interactive media rather than the media itself. The current study specifically examines how the role of choice in interactive media may influence children's school readiness across domains.

Further, many studies on young children's learning from interactive media are domain-specific, rather than domain general (Griffith et al., 2020). Here, we examine children's learning in three domains (vocabulary, math, and social-emotional learning). Children had the opportunity to engage with content designed to help them learn in each of these areas, and in all three areas, children in the choice condition demonstrated significant gains after using the app (children in the no-choice condition also demonstrated significant gains in math). While it is clear that children can learn from apps in all of these domains (Griffith et al., 2022), our study demonstrates that even when children have the option of playing games from any of these categories, they *can* and *do* learn in all of them, suggesting that apps can offer many domains of learning for children, rather than just one specialty.

The current study should also be considered alongside its limitations. First, researchers did not have control over the design of the stimulus. Both the choice and no-choice versions of *Lingokids* are commercially available. As such, children accessed different content within the app. While accessing different content is part of the design of this study (having a choice or not), children in each condition played with vocabulary, math, and social-emotional games for the same amounts of time. For more experimental control, it would be advantageous to provide children with false choices to ensure they have the same type of content accessed, but using commercially-available versions of the app improves the ecological validity of the current study. Another limitation is the assignment of condition by classroom, and thus teacher influence may impact our results. To mitigate this potential, we employed pre- and post- tests of our outcome variables and used change scores to control for children's knowledge at Time 1. The preschool we worked with also has teachers trained specifically to their curriculum and employs similar pedagogy across classrooms. While using change scores may not fully remove influence of teacher, we also met with the director of the preschool to ensure similar exposure to the outcomes of interest during the course of the study. We have described the teachers briefly in the Participants section, and we here again note that the preschool is play- and project-based, and thus children learn through experience, rather than lecture or lesson. There is no evidence of any teacher spending more time on any of our outcomes of interest than any other. Further, we see similar performance at both pre- and post-test for both classrooms randomly assigned to the choice condition. It is also important to note that the classroom in the no-choice condition scored higher than the other classes at pre-test in all outcome variables. This suggests that the no-choice classroom was not receiving worse instruction than the two classrooms in the choice condition. While we note the potential for teacher differences here as a limitation (as more robust

information would be acquired through running a similar study across many schools and classrooms), we have worked to mitigate the potential for this influence as much as possible. Finally, we had a small sample ($N = 31$) for our study. The sample size came from overestimating the number of children who would be eligible for our study and underestimating the amount of aversion to technology from parents. Further, we had budgetary limitations as we needed to buy devices for each child. Because the study is underpowered in some ways (noted above in the Supplemental Materials), it is difficult to extrapolate these findings to a wider population, and thus these results should be considered preliminary evidence for supporting agentic app designs for children.

Future Directions

Future research should look more closely at the role of choice in children's learning from media as well as children's experiences of absorption. As noted above, we did not have control over the design of the app. To isolate the feature of choice as a mechanism for improving learning outcomes, researchers should conduct studies where children are given no choice or a false choice in which they choose between two games but really the game will be the same so that all children see the same content. As such, the presence of having a choice can be isolated and better understood within the TIME model (Sundar, Jia, et al., 2015). Further, researchers should continue to attempt assessing absorption among young children. Though our measure was adapted from adult studies (Sundar, Go, et al., 2015) and created in consultation with early childhood experts, it was not reliable. Thus, it is possible that a standard questionnaire about user experiences is not appropriate for this age group. Instead, researchers should consider the use of biosensors, such as Galvanic Skin Response sensors and Facial Expression Analysis to determine children's enjoyment of and absorption with digital media. While young children may not be able

to vocalize their experiences in a consistent manner, these experiences can be observed and measured more objectively with biosensors. If absorption can be assessed in this manner, it could be included in future analyses of the TIME model as applied to children's media experiences. We note the importance of including this measure as theory on children's learning from media suggests that interest can act as a key influence in predicting learning outcomes (Fisch, 2000; Lieberman et al., 2009). Based on our theorization for the current study, it is likely that agency and interest and/or absorption are closely related in that children who feel more agentic while using media enjoy it more and thus learn more, and future research should continue exploring these connections.

Overall, the current study suggests that choice and repeated practice together can promote young children's learning. Educational media designers should seek opportunities to include these features in interactive media for young children, and parents should look for these features when seeking media for their children.

Author Note

CRedit Author Statement – the authors contributed to the following aspects of this manuscript:

Allyson L. Snyder: Conceptualization, Methodology, Formal Analysis, Investigation, Resources, Data Curation, Writing – Original Draft, Writing – Review & Editing, Supervision, Project Administration

Drew P. Cingel: Conceptualization, Methodology, Investigation, Resources, Writing – Review & Editing, Supervision, Project Administration, Funding Acquisition

Sofia V. Rhea: Formal Analysis, Investigation, Writing – Original Draft, Writing – Review & Editing

Jane Shawcroft: Investigation

Samantha L. Vigil: Investigation

Katherine Ong: Investigation, Writing – Original Draft, Data Curation

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Table 1*Zero-Order Correlations*

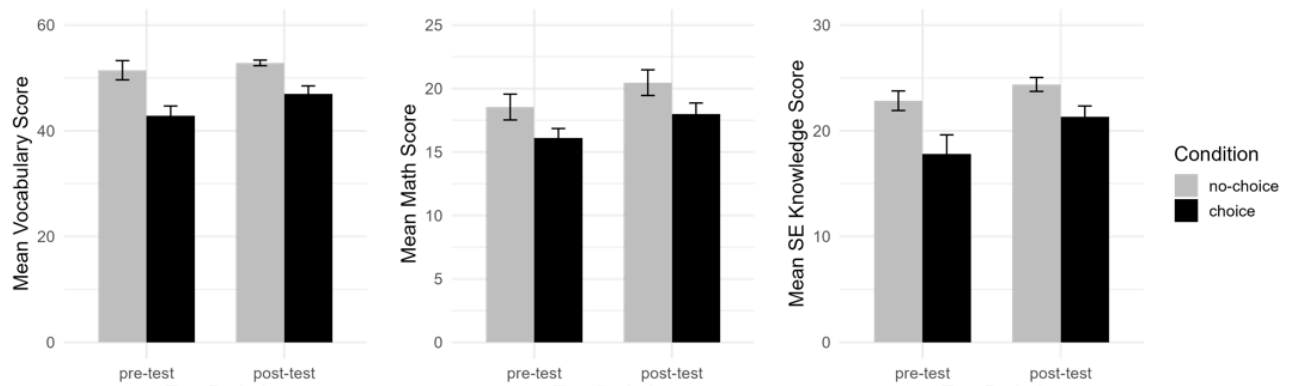
Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Condition												
2. Child Age	-.42*											
3. Parent Education	-.05	.04										
4. Household Income	.08	-.09	.36*									
5. Child Race	.15	-.04	.10	-.32								
6. Child Gender	-.24	-.03	-.03	.10	-.03							
7. Agency	.41*	.09	-.23	-.28	.20	-.09						
8. Vocabulary Change	.27	-.25	.34	.07	.36*	.12	.11					
9. Math Change	-.01	.04	-.08	-.01	-.09	-.15	.06	-.20				
10. SE Knowledge Change	.22	.01	.19	.03	.18	-.06	.22	.07	-.42*			
11. Completion Rate	-.34	.23	.35	.18	.14	-.23	-.27	.06	-.23	.03		
12. Play Time	-.01	-.39*	.03	.01	.21	.23	.11	.23	.03	-.04	.00	
13. Repetition Rate	.56**	.00	.06	-.02	.18	-.16	.23	.37	-.16	.26	-.23	.08

* indicates $p < .05$. ** indicates $p < .01$.

Note. Parent and child race were coded dichotomously such that White parents and children had a code for “1” and Hispanic/Latino, Black/African American, Asian, Native Hawaiian, Pacific Islander, American Indian, and Alaskan Native parents and children had a code for “2.” Parents and children who were more than one race also had a code for “2.” Parent and child gender were coded as “1” for men/boys and “2” for girls/women. Because we only had one non-binary participant, their data was excluded from the dichotomous gender coding but included for all other correlations. Condition was coded as “0” no-choice condition and “1” choice condition. *N*s for correlations range from 28-31.

Figure 1

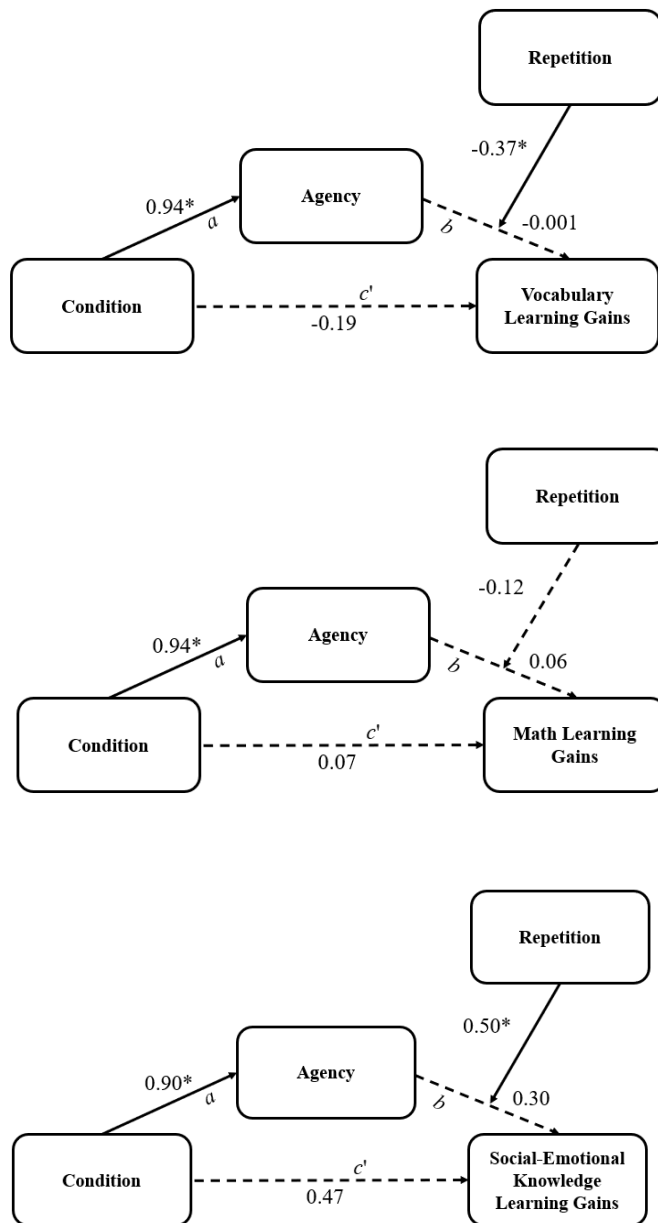
Means and Standard Errors by Group for Vocabulary, Math, and Social-Emotional Learning at Pre- and Post-Test



Note. The y-axis intervals are different to represent the untransformed scores for each variable.

Figure 2

Results for PROCESS Models (Vocabulary, Math, and Social-Emotional Knowledge)



Note. Condition was coded as “0” for no-choice and “1” for choice.