**Can Interactive Apps Promote Parent-Child Conversations in Low-Income Families?**

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**Abstract**

Smartphones are found to be a distraction, interfering with parent-child interaction. Our goal was to develop interactive apps for smartphones that would encourage rich conversations between parents and young children. We provided 76 lower-income families with three apps and recorded the parent-child dyads interacting with the apps when they first received them, and again three weeks later, keeping track of app use in-between. Results of this within-subjects short-term, longitudinal study suggest the apps elicited rich conversations between parents and their 3-4 year-olds. Most of the parent and child language measures increased over time reflecting richer conversations on our follow-up visit than our initial visit. The significant increase from the first visit to the latter visit in children's language complexity was associated with how frequently the family used the apps in between visits. The results suggest that interactive apps can help transform smartphones into opportunities for parent-child conversations and learning.

**Keywords**: Parent-child interactions; smartphones, language development, Apps, conversational turns

**Can interactive apps promote parent-child conversations in low-income families?**

## Introduction

Currently, over 92 percent of American adults ages 18-49 own a smartphone (Pew Research Center, 2019). Research on the effects of smartphones on social interactions suggests that the presence of a smartphone reduces the availability of attentional resources (Ward, Duke, Gneezy & Bos, 2017) and is negatively associated with closeness, connection and conversation quality (Przybylski & Weinstein, 2012). In parent-child interactions, smartphones are found to be a distraction, interfering with parents' connections with their children (Kushlev & Dunn, 2019). Indeed, increased parental smartphone usage is associated with parents initiating fewer verbal or nonverbal interactions with their children (Radesky et al., 2015). However, we know that parent-child interactions are helpful for child development, and smartphones are often present during those interactions. Our goal in the current study was to draw on the literature highlighting the specific types of social interactions that promote child language development to develop interactive apps for smartphones that will help transform the phone into an opportunity to elicit those types of parent-child interactions.

Children who have more opportunities during early childhood to participate in conversations at home with adults, tend to have better language and literacy skills when they start school (Hart & Risley, 1995). In the U.S., significant socioeconomic disparities in language and literacy skills are evident when children arrive at kindergarten (Reardon, 2013; Reardon & Portilla, 2016), and a significant portion of the socioeconomic disparities in early language skills is due to variation in language exposure in the home (e.g., Hoff, 2003). Exposure to language at home is associated with children's language development during early childhood, both within and across socioeconomic groups (e.g., Hoff, 2003; Huttenlocher, Haight, Bryk, Seltzer &

Lyons, 1991; Pan, Rowe, Singer & Snow, 2005; Weisleder & Fernald, 2013). It has also become clear that it isn't just the quantity of words children are exposed to that matters, but more nuanced features of those interactions (e.g., Rowe, 2012; Rowe & Snow, 2019). For example, opportunities for the child to engage in back-and-forth conversations, as an active participant, are more useful for learning than merely hearing a lot of words. Certain activities such as shared book reading, especially when interactive and dialogic, elicit conversations between parents and children and are shown to promote oral language skills (e.g., Mol, Bus, De Jong & Smeets, 2008). Here we ask whether apps that are designed to be used by parents and children together on smartphones, can also spark conversations and promote the types of talk we know are useful for language and literacy development.

***Use of apps in middle- and low-income homes and language and literacy skills***

While young children's access to books and shared reading opportunities varies, on average, by household income (Administration for Children and Families, 2002a), there are no longer income disparities in access to screen media. A survey conducted in 2017 found that 98 percent of families with children between 0-8 reported having a mobile device in the home. Lower-income families report that their 0-8 year-old children spend twice as much time using mobile devices (73 minutes per day) than higher-income families (37 minutes), on average (Rideout, 2017). The most common use of a mobile device for young children is to watch videos, followed by playing games and using apps. Furthermore, over 80 percent of parents reported downloading apps for children ages 2-4, with no differences by family income when downloading free apps (Rideout, 2017). A separate survey, also using a nationally representative sample of the U.S. population,

found that most parents reported co-use of mobile technology with their 0-8 year-old children, especially the younger children (Connell, Lauricella & Wartella, 2015).

This increased access to mobile technology for children from low-income families may help to level the playing field in early experiences that promote learning. Studies exploring the relationship between technology and literacy among children from middle- and upper-income households find that preschool-age children with more access to tablets had stronger letter-sound awareness and name writing skills (Neumann, 2014). A positive association between the use of writing apps and print awareness, print knowledge, and sound knowledge has also been identified in middle-class households (Neumann, 2016). In a recent study with children attending Head Start, children who used educational apps on their mobile devices had significantly better print knowledge than children who did not use educational apps (Guzman, 2019). In a separate study using an experimental design, researchers randomly assigned 22 preschoolers from low-income families to use educational apps or entertainment apps for 3 months. Children using the educational apps demonstrated significant gains in their literacy skills when compared with children who used entertainment apps (Griffith & Arnold, 2019). Thus, there is evidence of a general positive relation between use of educational apps and language and literacy skills for preschool-aged children across socio-economic groups. In addition, most of this research focuses on educational apps that children can use on their own, and that explicitly teach early literacy skills such as letter names, vocabulary, reading and writing. We have limited information about apps that are designed to elicit conversations between caregivers and young children to promote parent-child interaction, as in the current study.

***Young children are social learners***

Children learn language from their social interactions with others. During typical free play activities at home between parents and 3-4 year-olds, there are certain features of social interactions that are found to promote preschool-aged children's language development. Specifically, more than just speaking a lot to children, interactions where the parent uses more diverse and sophisticated vocabulary, asks questions, provides explanations, uses longer sentences, discusses abstract topics such as reminiscing about past events with the child, and keeps the child engaged in more back-and-forth conversational turns are associated with more positive language and early literacy outcomes for children (e.g., Huttenlocher, Waterfall, Vasilyeva & Hedges, 2010; Romeo et al., 2018; Rowe, 2012; Weizman & Snow, 2001). Thus, providing parents with encouragement and opportunities to engage socially with their young children in these ways should promote children's language and literacy development.

Engaging with books is one context shown to promote children's learning (e.g., Senechal & Cornell, 1993; Snow, Burns & Griffin, 1998;). Importantly, *dialogic* reading, is found to promote language and literacy skills in typically-developing preschoolers more than merely reading the text of books to children (Mol et al., 2008), likely because it also engages the child in a discussion about the text, using language to make predictions and answer questions (Whitehurst et al., 1988). Indeed, when the dialogic approach is applied to co-viewing educational television, similar results are found. For example, in one study, preschoolers who were exposed to storybook videos and had their parents co-view the videos while using dialogic techniques (stop and ask questions, encourage child comments) scored higher on story comprehension and vocabulary learning than children in other groups who viewed the same videos but without the dialogic parent interaction (Strouse, O'Dougherty & Troseth, 2013).

Thus, we know that high quality social interactions with children, around play or books or television, can promote language and literacy development, and that learning from media requires sensitivity to young children's social expectations (e.g., Hirsh-Pasek et al., 2015). The question at hand is whether we can draw on the literature to develop apps that help to elicit these types of social interactions between parents and children in low-income families, as recent reviews highlight the need for digital content for young children that "prompts" rather than "substitutes" for social interaction (Hassinger-Das, Brennan, Dore, et al., 2020).

***Using the language input literature to inform app development***

We drew from the literature identifying the specific features of children's home language environments that promote language development (e.g., Rowe & Snow, 2019) to create a theory of change for each app. The app *Photo Play* was designed to elicit parent-child conversations that are decontextualized, or about the past or the future. We know from a large body of literature, that talking about the past with preschool children is positively associated with children's language comprehension, vocabulary, syntax and narrative skills (e.g., Demir et al., 2015; Peterson, Jesso, & McCabe, 1999; Reese, Leyva, Sparks, & Grolnick, 2010). One added benefit of discussions of the non-present (past and future) is that they tend to be more syntactically complex than discussions of the here-and-now (Demir et al., 2015), as it takes longer utterances to discuss more abstract topics. Thus, we designed the app so that parents could import photos from their phone for discussions with their children. We embedded prompts for the parents, suggesting questions they might ask their children such as: "What do you remember about our day in this picture?" or "How were you feeling when this happened?" or "Would you like to go back there again? Why?", etc. Research shows that onscreen prompts of

this sort during television viewing can help elicit parent-child interactions that promote language skills (Fisch, Akerman, Morgenlander et al., 2008). Finally, we embedded the ability to decorate the picture to make it fun and give the child something to do while the parent and child are talking. In sum, the theory of change is that *Photo Play* will increase parent-child conversations about the past, which will also expose children to more complex language and help promote child language skills through engaging in those decontextualized conversations (e.g., Rowe, 2013).

A second app, *Story Mixer*, focuses on using and promoting vocabulary skills in preschoolers. Here the parents are encouraged to read their children familiar nursery rhymes with occasional words removed as fill-in-the-blanks: "Jack and Jill went up the ____". Then they are invited to choose a picture of an object to drop into the story mixer machine along with two attributes (a noise and a movement). After the mixing is done the new version of the object is revealed and the child is prompted to describe it and give it a name ("a jumping, snorting, ice cream cone!"), insert it into the story, and then continue on with the story until the next blank. The goal is to provide children with the opportunity to listen to familiar nursery rhymes and to have a say in changing those rhymes by creating their own silly additions which require them to verbalize phrases that include adjectives, verbs and nouns. The use of adjectives and verbs is intentional because young children's vocabularies are made up primarily of nouns (e.g., Bates et al., 1995) and verbs and adjectives are harder to learn (Gentner & Boroditsky, 2001). Further, we incorporated prompts for the parents to help promote conversations around the story as it develops. In sum, exposure to and opportunities to use verbs and adjectives in different combinations through conversation, as provided in this app, may help facilitate vocabulary development (Harris, Golinkoff & Hirsh-Pasek, 2011).

A final app, *Animal Antics*, draws from the literature on conversation to promote back-and-forth conversational turns between parent and child. The research suggests that preschool aged children who engage in more conversational turns at home have greater language skills (e.g., Romeo et al., 2018). In this app, parents and children choose from a variety of settings (doctor's office; grocery store) and each person becomes one of the two animals in the scene. They record a dialogue using their own voices, taking turns in the conversation, and then play it back in the app and hear their voices come out of the animals' mouths. The app provides prompts and changes of scenes within each setting to keep the conversation going, provides feedback by tracking the number of conversational turns in a bar along the top, and allows for saving and playing back the conversations. The theory of change here is that the settings will provide many topics for discussion, the personalization of becoming the animals will be engaging, and the app will provide an opportunity to prompt back-and-forth conversations between the parent-and child (Hassinger-Das et al., 2020).

***Intervention approaches to increase parent-child interaction at home***

Existing approaches to increase parent-child interaction and bolster children's home language environments primarily focus on providing information to parents about the importance of talking with their young children. Indeed, research shows that regardless of socio-economic status, parents who know more about child development are more likely to interact with their children in ways that promote language development (e.g., Leung & Suskind, 2020; Rowe, 2008; Vernon-Feagans et al., 2008). Parent interventions of this sort have seen some success (e.g., (Adamson, Bakeman, Suma & Robins, 2019; Biel et al., 2020). For example, results of a randomized controlled trial of the 3T's home visiting curriculum found that providing low-

income parents with knowledge and child-rearing strategies resulted in these parents talking more and engaging their children in more conversational turn-taking than parents in a healthy lifestyle control group (Leung et al., 2018). Providence Talks, a city-wide initiative to inform caregivers of the importance of speaking with their children, also finds positive results from this type of model (Wong, Thomas & Boban, 2020). And, smaller-scale training studies that target specific features of parent communication have also been successful in promoting those features of communication whether focused on using baby talk (Ramirez, Lytle & Kuhl, 2020) or gesture (Rowe & Leech, 2019) with infants, or providing explanations and having abstract conversations with preschool-aged children (Leech, Wei, Harring & Rowe, 2018). Thus, providing parents with information about how they can help improve their children's language development has been found to be a useful way to enhance children's home language environment. Here, we build on this premise and provide parents with specific information and examples of how they can use the apps to engage in fun interactions with their children that may help to promote language development.

***The current study***

Building on this prior literature, our goals for the current study were to determine whether we could create some interactive apps for smartphones that parents and 3-4 year-old children could use together which would elicit rich conversations and language-promoting interactions. Our focus is on lower-income families, as the literature suggests children in these families on average have fewer opportunities to engage in rich language-building conversations at home (Golinkoff, Hoff, Rowe et al., 2019) than their peers from higher-income homes. However, even within this low-SES sample, we were interested in whether the families would differ in how they

communicated when using the apps with their children based on family and child characteristics found previously to relate to parent-child interaction in other contexts including parent education (e.g., Golinkoff et al., 2019), child age and language abilities (Huttenlocher et al., 2010), and child gender (Leaper, Anderson & Saunders, 1998). We examined whether interactions with the apps would change over time after several weeks of apps use, and we were interested in examining whether there would be any difference in use for parents who spent more time with the apps, or who were also provided with additional information about the benefits of conversing with their children. Our specific research questions are as follows:

1. Do the apps elicit conversations between parents and children, and if so, what are the linguistic characteristics of those conversations at visit 1 and visit 2?
2. Do interactions with the apps, or change over time in interaction with the apps, vary based on differences in parent socioeconomic status, child age, gender or language skills?
3. Do interactions around the apps change over time with more vs. less experience using the apps?
4. Does providing some parents with additional information influence changes in parent-child interactions?

## Materials and Methods

### *Participants*

76 children between 33 and 53 months old (M=42.61 SD=4.89) participated with a parent in this study. Families were recruited by an online research firm that used social media platforms, panels, and email listservs to share information to prospective families about this study. To be eligible, parents had to reside within one hour of Boston, have a yearly income less than $99,000

(the median income for a family of four in the greater Boston area), speak English as primary language in the home at least 75% of the time, and own a smartphone with internet access. Families designated one parent as the participant with their child and that did not change over time. Eight of the parents identified as male and 68 as female. The average years of education for the participating parent was 15.6 years (range 12-22 years), equivalent to some college but not completion of a 4-year degree which would be equivalent to 16 years. Demographic information on the sample is presented in Table 1.

[Insert Table 1 about here]

***Procedures***

Participation in this study consisted of two home visits with a three-week period in-between. Visits took place in parents' homes at times of their choosing. Before the first visit families were randomly assigned to one of two groups, the apps-only group or the apps-with-info group. The groups did not differ significantly on any of the demographic factors (Table 1).

During the first visit researchers assisted parents in downloading the apps onto their phones. Parents then filled out a demographic questionnaire while a researcher administered language and pre-literacy assessments with the child. For parents in the apps-with-info group, the parent was next asked to use a literacy scavenger hunt app described below (Leech et al., in prep). Then, for all families, the parent and child were video recorded engaging with the three different interactive apps for approximately five minutes each. To do this, parent-child dyads were asked to sit in a quiet, comfortable area in their house. An iPad was set up on a tripod across from the dyad so the recording could capture the parent and child conversing and using the apps. Parents were instructed to begin playing and the researcher moved away from the dyad and the tripod until the dyad finished playing with the apps. Following the app interactions,

parents and children were also video recorded interacting with a toy and an e-book. At the end of the visit, the apps-with-info group was shown how to log into a website to receive informational content in the form of videos. All families were asked to play with the three apps with their child for a little while every day for the next three weeks, and all received periodic reminder text messages. The apps themselves recorded the frequency and duration of use during the three-week period. The current study presents the findings of the interactions around the apps only.

The second home visit occurred three-weeks (min 11 days, max 35 days SD = 3.34) after the first visit. During this home visit, we again video recorded the parent and child interacting with the three apps for approximately five minutes each. At the end of the visit parents filled out a questionnaire reporting what they liked or didn't like about the apps.

***Materials***

*The apps:* As described earlier, parent-child dyads used three apps designed to embody and support research-based objectives for promoting language and literacy skills such as decontextualized language use, sustained conversations and rich vocabulary use. In addition, these apps incorporated personalization features (i.e, incorporating the child's own voice; importing photos from the parents' phone) to help make them more appealing. The three apps, created in collaboration with FableVision Studios, were: *Photo Play, Story Mixer*, and *Animal Antics* (see Figure 1). *Photo Play* centers around parents using app-led prompts to discuss photos of their families which they import into the app from their phone, while incorporating features that allow dyads to decorate photos and play games with their own photos. *Story Mixer* is a story game that allows dyads to change the objects in popular nursery rhymes to create their own unique stories. *Animal Antics* is a performance-based app where dyads choose from scenarios to

perform their own story with the child and parent recording their own voices as characters having a conversation in different settings.

[Insert Figure 1 about here]

*Parental messaging:* Parents in the apps-with-info group received two types of extra information. First, at visit 1 they used a literacy scavenger hunt app which featured a virtual 360-video to immerse parents in a hypothetical neighbor's home who holds a broad literacy script. Through this app, a parent could see a home through the eyes of a neighbor to reveal how everyday routines could be carried out in ways that promote literacy. Second, they received text messages with links to didactic/instructional videos (total of nine videos in three weeks) featuring a woman providing tips on ways to interact with preschoolers that promote language development, pre-recorded videos of dyads (not subjects) playing with the apps and engaging in back-and-forth conversation, and additional prompts to encourage using the apps. More specifically, the videos varied in topics as follows: The first was a welcome message with a focus on promoting parental efficacy by explaining to parents that their interactions with their children can promote language development. The second video was a message from our developers, FableVision, about the apps; videos 3-5 focused on the benefits of engaging in conversations with children, asking questions, talking about the past and the future, and using a variety of words; videos 6-9 were about using the apps outside the home, extending what you were doing with the apps to other situations, and about reflecting on what you've learned in the study. Parents were prompted with text messages to watch the videos, which were shared approximately every two to three days and could be watched more than once.

***Measures***

*Children's Language Skills:* Children's receptive language skills were assessed using the Quick Interactive Language Screener (QUILS; Golinkoff et al., 2017). The QUILS is a 48-item assessment designed to measure three components of receptive language – vocabulary, syntax, and language learning - among three- to five-year-olds in approximately 20 minutes. The QUILS was administered on a tablet and each item was presented in a multiple-choice format. Raw scores represent the number of items correct in each measured component and across all 48-items and scaled scores are based on child age. Most children (n=62) were given the QUILS during Visit 1. For those who missed it during the first session for lack of time, it was given at the second visit.

*Quantity and quality of parent and child speech:* The parent-child interactions with the three apps were transcribed verbatim by research assistants trained to reliably use the CHAT conventions of the Child Language Data Exchange System (CHILDES; MacWhinney, 2000). A separate research assistant verified each transcript for accuracy, paying attention to check utterance boundaries and question marks. The unit of transcription was the utterance, defined as any sequence of words that is preceded or followed by a change in conversational turn, intonation, or a pause. Automated analyses of the transcripts using the CLAN program yielded the mean length of utterance (in morphemes; MLU) by each speaker, the number of total words (Tokens) and different words (Types), which serve as a measure of overall quantity of speech and vocabulary diversity, and the number of utterances that contained a question (Questions). We use proportions in our analyses where we divide the total number of questions by total utterances. Finally, we also applied some additional coding to the transcripts to identify the

number of conversations (Conversations) – defined as a series of turns linked together by a common theme or topic – and the average number of turns between parent and child within each conversation (Turns). For this conversational turn coding, two coders initially coded 15 percent of the transcripts separately. These transcripts were then compared to establish reliability and the percent agreement was 98% with a mean Cohen's kappa of .91 for conversations and the percent agreement was 99% witrh a mean Cohen's kappa of .98 for conversational turns.. One of the two coders then coded the rest of the transcripts.

### *Hypotheses*

We expected variation across families in these measures of quantity and quality of child-directed speech. We hypothesized that variation may be positively associated with parent education, child age or language ability, and having a girl child, based on previous studies. We hypothesized that the *Photo Play* app would elicit longer utterances (MLU) through talk about the past, that the *Story Mixer* app might elicit more diverse vocabulary, and that the *Animal Antics* app would elicit more extended conversations. Thus, taken together, using all of the apps more frequently may be associated with increases in children's production of vocabulary (word types), syntax (MLU) or conversational turns, all valid indicators of developing language abilities.

## Results

### *Descriptive Statistics*

During both visit 1 and visit 2 the length of time that the parents and children interacted with the apps varied (V1: M = 14.32 min, SD = 3.50 min; V2: M = 12.23 min, SD = 2.60 min). To account for differences across dyads in the duration of their app interactions, analyses on number

of total words, different words, and conversations were conducted using rate data calculated by dividing the raw counts by the duration in minutes. This resulted in rate-per-minute variables. MLU is already a ratio of the mean number of morphemes per utterance, and questions was measured as the proportion of utterances that were questions. In Table 2 we present the descriptive statistics for these measures of parent and child language use during the app interactions at both visits and note which measures increased significantly from visit 1 to visit 2 for all of the apps combined (for data on each app separately see the Appendix).

[Insert Table 2 about here]

As is apparent in Table 2, parents and children communicated quite a bit when using the apps. On average, they engaged in 1 conversation per minute, and the conversations consisted of approximately 10 "turns" total, meaning 10 back-and-forths between parent and child before moving on to a different conversation. Examining the talk during these conversations at the first visit, parents used, on average: 74 words per minute, 14 different words per minute, utterances that averaged over 4 morphemes long (MLU), and 36 percent of their utterances were questions. The children produced an average of 16 words per minute, 5 different words per minute, and utterances that averaged approximately 2.5 words long. It is important to point out that there was also wide variability in parent and child speech measures in this sample. For example, at visit 1, on average parents produced 14 different words per minute, but there was a range in vocabulary diversity from 9 to 29 words per minute.

Most of the measures increased significantly from visit 1 to visit 2 suggesting that using the apps may be associated with more sophisticated conversations over time, a question we address further below. On average, children increased in their MLU, word types and word tokens from visit 1 to visit 2, and parents increased in their MLU, word types and questions

posed. Furthermore, the average length of conversations (number of turns) between parents and children increased from visit 1 to visit 2 but this effect was marginally significant ($p<.10$).

***Correlations***

To answer our second research question, we conducted correlation analyses to determine whether there were significant associations between any of the parent or child background factors and how the families interacted with the apps at visit 1. Our Pearson correlations indicate that despite the fact that this is an entirely lower-income sample, there were some relations between family socioeconomic status and parent-child communication at visit 1. For example, parents with higher incomes produced more word tokens ($r = 0.34$, $p<.01$) than parents with lower incomes and parents with more education asked more questions ($r = .28$, $p<.05$) than parents with less education. On average, parents used longer utterances (MLU) with older children ($r = 0.36$, $p<.01$) and with children who had higher QUILS scores ($r = 0.35$, $p<.01$), and there was no difference between how parents talked to boys versus girls. The only significant associations between demographic factors and children's speech during app use at visit 1 was a positive relationship between child MLU and child age ($r = 0.39$, $p<.001$) and between child MLU and child QUILS scores ($r = 0.30$, $p<.05$), suggesting, not surprisingly, that older children and children with better language skills produced speech that was more syntactically complex during the interactions.

We examined the same correlations for the interactions at visit 2, controlling for the same speech measure at visit 1 to see if there was an association between demographic factors and the *change in conversation measures* from visit 1 to visit 2. The results of the partial correlations show that parents of girls used more word types ($r = 0.28$, $p<.05$) than parents of boys at visit 2

controlling for parent word types at visit 1. Girls also used more diverse vocabulary (word types $r = 0.30$, $p<.05$) than boys during visit 2 app use, controlling for word types at visit 1. These results suggest that parents of girls and girls themselves increased more over the three weeks in their use of vocabulary when interacting with the apps. Additionally, as we saw at visit 1, a positive relationship remained between child MLU and child age ($r = 0.24$, $p<.05$), and child MLU and child QUILS scores ($r = 0.24$, $p<.05$) controlling for visit 1 app talk.

***App use***

Here we report on the cumulative usage data collected via the apps during the period between visit 1 and visit 2. Families varied in the number of days between their visits, thus we present these results in a "minutes per-day" of app use metric. There was large variation in the number of minutes per day families used the apps. The average for the sample was approximately 15 minutes per day (M=14.5, SD=7.0), but there was a range from less than one minute to over 33 minutes per day, on average. There were no group differences in frequency of app use for the apps-only versus apps-plus-info groups. As shown in Figure 2a, on average, families used *Animal Antics* the most (M=53mins), followed by *Story Mixer* (M=42mins), followed by *Photo Play* (25mins).

The majority of app use occurred between 9am and 9pm, with 6-9pm being the most popular time on both weekdays and weekends. As shown in Figure 2a, the apps were used most during the first week following visit 1 (M=59 mins per week per family). There was a significant drop in usage from week one to week 2 (M = 31 mins per week), which then remained stable for week 3. It is interesting to note, however, that while the families used the apps less frequently in weeks 2 and 3 than week 1, the mean length of a session of app use increased over time.

Specifically, as shown in Figure 2b in week 1 the mean session length was 2.39 minutes and increased by .75 minutes in week 2 and an additional .42 minutes in Week 3.

[Insert Figure 2 about here]

Finally, app use did not differ by child age or gender. Parents who were more educated engaged in more app use between visit 1 and 2 than parents with less education ($r = .33$, $p<.01$), yet the relationship between parent income and app use was non-significant. Further, children who had greater language skills on the QUILS engaged in more app use than children with lower QUILS skills ($r = 0.26$, $p<.05$).

***Does app use predict change in parent-child interactions from visit 1 to visit 2?***

To answer our third research question, we first ran partial correlation analyses to determine whether the duration of app use in-between visits predicted the positive change we saw in children's MLU, word tokens and word types and parents' MLU and word types. These are presented in Table 3. The only significant association was that children who engaged in more app use had greater MLU at visit 2 ($r = 0.45$, $p<.001$) controlling for MLU at visit 1.

[Insert Table 3 about here]

To follow up on the partial correlation analyses we ran multiple regression analyses to determine whether app duration continued to predict child MLU at visit 2, controlling for child MLU at visit 1 and other potential controls (parent education, gender, treatment group). These models are presented in Table 4. Model 1 shows that 28 percent of the variance in child MLU at visit 2 is explained by child MLU at visit 1. In Model 2, we see that the duration of app use in-between visits is a significant predictor, controlling for MLU at visit 1, and explains an additional 18 percent of the variance in MLU at visit 2. The remaining models show that the significant effects of MLU at visit 1 and duration of app use hold when controlling for other demographic

factors including education, child language skills, gender, child age and treatment group. There were no significant interactions between treatment group and the other predictors in any of the models. In sum, children who were producing longer utterances at visit 1, and who used the apps more in-between visits, produced longer utterances during app use at visit 2. Follow-up analyses of the language use during each app separately suggest that these regression results hold for predicting change in MLU in the *Animal Antics* app interactions only, in the *Photo Play* app only, but not with *Story Mixer*. This is not necessarily surprising, as *Animal Antics* and *Photo Play* were the apps designed to elicit more extended utterances.

[Insert Table 4 about here]

***Effects of providing parents with additional information***

To answer our final research question about differences between the apps-only and apps-with info group, we conducted several analyses. First, as shown in Table 2 we found that the only difference across groups over time was that parents in the apps-with-info group produced more questions than parents in the apps-only group at visit 2. However, this difference was no longer significant when controlling for the number of questions parents produced at visit 1. Further, there were no other significant differences between groups in the change in linguistic measures from time 1 to time 2.

We also examined how often the parents in the apps-with-info group accessed the information provided. Recall, those parents were texted with links to a website where they could view videos providing info about language and literacy development and about how to effectively use the apps to promote their children's learning. There were a total of 9 videos that could be viewed by these families. We tracked whether families viewed the videos, and if so, how many they viewed on the website. On average, the families accessed only 2.08 videos (SD

= 2.63) with a range from 0-9, and sixteen of the 38 families in this group did not access the videos at all. As shown in Table 5, there was a significant positive association between the number of videos viewed and parent vocabulary diversity and parent-child conversations at visit 2, controlling for these same measures at visit 1. This suggests that while some parents did not watch any of the videos, watching more of the videos was associated with an increase in parent-child conversations and in parent vocabulary use when using the apps with their children. This finding was driven by the app use during the *Animal Antics* app in particular.

[Insert Table 5 here]

**Discussion**

Our goal was to develop interactive apps for smartphones that would encourage rich conversations between parents and young children. In this way, the smartphone might actually enhance parent-child interaction rather than detract from it (e.g., Radesky et al., 2015). To summarize our findings, we found that the apps did indeed elicit rich conversations between parents and their 3-4 year-olds. As a point of comparison, as noted we did also videotape these same families engaging with an e-book and the measures are very similar across both electronic contexts. For example, child MLU during the apps at visit 2 was 2.69 compared to 2.67 for the e-book, and child word types with the apps averaged 6.5 words per minute at visit 2 compared to 4.6 for the e-book. Most of the parent and child language measures examined during conversations with the apps increased over time indicating richer conversations on our follow-up visit than our initial visit. In regard to vocabulary use these increases were particularly strong in dyads where the child was a girl rather than a boy. For the case of MLU, which is the syntactic complexity of children's speech, the significant increase from the first visit to the latter visit was predicted by how frequently the family used the apps in between visits. Finally, we found no

difference between the apps-only group and the apps-with-info group in how the parents and children interacted with the apps; however, further examination of the data from the apps-with-info group alone revealed a positive association between how many informational videos the families accessed and increases in the number of parent-child conversations and parent vocabulary use during the apps from visit 1 to visit 2. Below, we expand on the importance of some of these findings, comment on the implications for screen media more broadly, and discuss some of the limitations of this study.

One of our more exciting findings is that the conversations parents and children were engaging in around the apps became more sophisticated over time in terms of the vocabulary and syntactic complexity of the talk. In this way, the apps may have provided a scaffold for parents and children to engage in rich conversations. For example, the app *Photo Play* was designed to elicit conversations between parents and their children about the past with parents importing photos from their camera to discuss. We know that talking with preschool-aged children about shared past experiences is an activity that promotes use of more complex syntax and oral language and literacy skills (Uccelli, Demir-Lira, Rowe, Levine & Goldin-Meadow, 2019; Rowe, 2013). It was encouraging to see in the data how the conversations became more elaborate and sophisticated over time, as children became more experienced at having these discussions. For example, below we include a sample of a *Photo Play* conversation between and father and child in the study at visit 1 and then again at visit 2. It is evident that the child is able to contribute more to the conversation at the latter visit, and in particular the child's utterances are longer. Indeed, we found a positive association between the amount the apps were used during the study and the change in children's mean length of utterance from visit 1 to visit 2. This

suggests that practice conversing around the apps may provide children with opportunities to produce longer utterances and potentially improve children's productive syntax abilities.

| Visit 1: | Visit 2: |
|---|---|
| *FAT: where was the picture taken? | *FAT: is this you? |
| *CHI: with Mama. | *FAT: yes. |
| *FAT: who else is in the picture? | *CHI: yeah. |
| *CHI: Didi. | *FAT: what were you doing? |
| *FAT: what did you do before this? | *CHI: driving. |
| *CHI: before. | *CHI: you were sitting in the back. |
| *CHI: I just do two. | *CHI: and I was driving. |
| *FAT: okay. | *FAT: you were driving the tractor? |
| *CHI: and I'm little. | *CHI: yeah and we went cherry picking. |
| *FAT: what did you do after this picture? | *FAT: and we went cherry picking? |
| *CHI: um. | *CHI: yeah. |
| *CHI: my two. | *FAT: where was the picture taken? |
| *FAT: okay. | *FAT: at the farm? |
| *FAT: did you like being there? | *FAT: or where? |
| *CHI: yeah. | *CHI: in the farm. |
| | *FAT: right. |

As another example, the *Animal Antics* app was designed to promote turn-taking in conversations where child and parent each pretended to be one of the characters in the app and recorded themselves having a back-and-forth conversation. While we only saw a marginally significant increase over time in the number of turns per conversation during app use, with *Animal Antics* we noticed that children were participating more and elaborating more in their "turn" of the conversation, thus possibly also contributing to the increase over time in their vocabulary and syntax use. Below is an example of a mother and child at visit 1 and visit 2 playing with the app.

| Visit 1: | Visit 2: |
|---|---|
| *MOT: alright what's monkey going to say? | *MOT: now I'm going to say. |
| *MOT: want to do it? | *MOT: I'm going to buy it for you. |
| *MOT: are you monkey? | *MOT: and then what would rooster say to that? |
| *MOT: what's monkey going to say? | *CHI: why you buy? |
| *MOT: he's at the doctor remember. | *CHI: why you buy sheep? |
| *CHI: hello. | *MOT: and sheep will say. |
| *MOT: hamster doesn't feel well. | *MOT: I'm going to get some chocolate too. |
| *MOT: do you want to say why hamster doesn't feel well? | *MOT: what flavor should I get? |
| | *MOT: what do you think? |

| | |
|---|---|
| *CHI: yeah.<br>*MOT: alright.<br>*MOT: tell me what [/] what hurts hamster?<br>*CHI: what's hurting hamster?<br>*CHI: what's hurting?<br>*MOT: well what do you think he has?<br>*MOT: do you think he has a belly ache?<br>*MOT: do you think he has a head ache?<br>*MOT: do you think he has a sore throat?<br>*MOT: what do you think?<br>*MOT: so say whatever you think hamster had.<br>*MOT: pretend you're hamster.<br>*MOT: you're a hamster.<br>*MOT: what are you going to say?<br>*CHI: hello. | *MOT: what flavor should I get?<br>*CHI: you can get.<br>*CHI: you can strawberry.<br>*CHI: I want.<br>*CHI: strawberry.<br>*MOT: I'm going to say.<br>*MOT: I'm going to ask you a question.<br>*MOT: do you want one scoop or two scoops?<br>*CHI: I want one scoop of vanilla.<br>*MOT: oops try it again cause you just did not hold it long.<br>*CHI: I want chocolate and a double chocolate.<br>*MOT: ooh.<br>*MOT: ooh so you want two scoops.<br>*MOT: do you want rainbow sprinkles or chocolate sprinkles?<br>*CHI: I want rainbow. |

Taken together our results suggest that providing parents and young children with apps that are designed to be fun and elicit conversations, and giving them opportunities to play with the apps, may promote conversations between parents and children. Of course, one important limitation of this study is that we did not include a control group who did not use the apps in-between visits, and thus we cannot make any claims about the apps themselves causing improvements in the linguistic measures. Further, as is often the case with this type of research it is possible that being video recorded interacting in their homes might have led the parent-child dyads to interact in ways different than if they were not being video recorded. We did choose to conduct the study in families' homes, and to remove the researcher from view while videotaping to minimize any effects of the researchers, yet we do not know if these interactions we captured are similar to interactions between parents and children without our presence.

Given previous research showing links between parents' knowledge of child development and parent-child interactions (e.g., Leung, Hernandez & Suskind, 2020; Rowe, 2008), we also hypothesized that it would be helpful to provide parents with additional information about how to promote oral language and literacy skills through conversations with children. Thus, we were

somewhat disappointed to see that we did not have a main effect of our treatment group (apps-with-info) over and above the apps-only group. On the one hand, this can be seen as a positive result in that the apps alone were sufficient to promote rich conversations between parents and children. On the other hand, further analysis of the data from just the apps-with-info group did show that within that group the parents who accessed more of the information we provided changed over time in their interactions in the ways we would predict – specifically they used more diverse vocabulary and engaged in more conversations.

One challenge and limitation of our study was that about 40 percent of the treatment group did not in fact access the information we provided. This may be due to a variety of factors. First, we learned from our app analysis that parents and children most often used the apps between 6-9 pm. Yet, we sent our text messages with info to parents in the mornings, during a time when they may not have been able to engage with the material. Second, we encouraged parents to watch the videos but did not provide any additional incentive to do so, thus those who did watch the videos may have differed from those who did not in other ways we did not measure, such as their desire for parenting information or the time they had to spend with children. Nevertheless, we saw some positive associations between providing parents with additional information about children's language and literacy development and their interactions with their children for those who chose to access the material.

More broadly our results have important implications for thinking about the role of screens in parent-child interactions. Parents are wary of screen time, yet not all screen time is bad for children's language development. For example, a recent systematic review of the literature indeed found a negative association between the quantity of children's screen time and their language development, yet there was a positive association between children's language

development and engaging in educational programs or parent-child co-viewing (Madigan, McArthur, Anhorn, Elrich & Christakis, 2020). Thus, more research is needed to understand the different types of screen time and their positive and negative effects. Here, we developed fun and engaging activities that brought parents and children together around smartphones to have conversations. We were able to show that the interactions around the apps elicited rich uses of language between parents and children. However, in this study we didn't analyze the talk in a nuanced way to also determine how much of the conversation is about the details negotiating the use of the apps, rather than more substantive content. Indeed, studies comparing reading with typical books versus e-books find that these comments about electronic format during interaction can hinder children's comprehension (e.g., Krcmar & Cingel, 2014), and our goal was to elicit conversations about the past or about scenarios and stories, not about the apps themselves. Anecdotally, we noticed talk about using the apps seemed lower in visit 2 than visit 1, but we plan to investigate this more systematically in future work. Nonetheless, this work suggests that the smartphone is potentially less disruptive (e.g., Kushlev & Dunn, 2019) and instead could be a facilitator of high-quality parent-child interactions. This is important because parents bring their smartphones with them virtually everywhere they take their children; on the bus, to the grocery store, to the restaurant or the dentist office. Thus, these apps, and others like them, can potentially help transform smartphones into opportunities for parent-child interactions and learning.

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Table 1. Participant demographics

| | Full Sample (N=76) M (SD) | Apps-Only (N=38) M (SD) | Apps-with-Info (N=38) M (SD) |
|---|---|---|---|
| Child age (months) | 42.61 (4.89) | 43.37 (4.95) | 41.84 (4.78) |
| Parent education (years) | 15.59 (1.99) | 15.71 (2.17) | 15.47 (1.83) |
| | N (%) | N (%) | N (%) |
| Gender (male/female) | | | |
| Parent | 8/67 | 3/35 | 5/32 |
| Child | 38/38 | 17/21 | 21/17 |
| Child racial/ethnic identity | | | |
| Caucasian | 39 (51.3%) | 23 (60.5%) | 16 (42.1%) |
| African American | 13 (17.1%) | 5 (13.2%) | 8 (21.1%) |
| Hispanic/Latino | 2 (2.6%) | 1 (2.6%) | 1 (2.6%) |
| Asian | 2 (2.6%) | 2 (5.3%) | 0 |
| Mixed | 20 (26.3%) | 7 (18.4%) | 13 (34.2%) |
| Parent Income | | | |
| 0 to 49,999 | 22 (29.0%) | 11 (29.0%) | 11 (29.0%) |
| 50,000 to 74,999 | 27 (35.5%) | 15 (39.5%) | 12 (31.5%) |
| 75,000 to 99,999 | 27 (35.5%) | 12 (31.5%) | 15 (39.5%) |

*Table 2. Descriptive statistics of child and parent language measures during visits 1 and 2*

| | | Overall | | | Apps-Only | | | Apps-with-Info | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Visit 1** | **Visit 2** | ***p*** | **Visit 1** | **Visit 2** | ***p*** | **Visit 1** | **Visit 2** | ***p*** |
| **Child** | **MLU** | 2.49 (0.69) | 2.69 (0.66) | 0.013 | 2.57 (0.77) | 2.81 (0.68) | 0.058 | 2.42 (0.60) | 2.56 (0.63) | 0.117 |
| | **Types** | 5.47 (1.73) | 6.51 (2.19) | 0.000 | 5.08 (1.89) | 6.66 (2.44) | 0.000 | 5.84 (1.50) | 6.37 (1.93) | 0.117 |
| | **Tokens** | 16.00 (6.70) | 18.17 (8.78) | 0.012 | 14.98 (6.87) | 18.85 (10.03) | 0.002 | 16.99 (6.46) | 17.51 (7.45) | 0.662 |
| | **Questions** | 0.09 (0.10) | 0.09 (0.06) | 0.554 | 0.11 (0.13) | 0.09 (0.06) | 0.570 | 0.08 (0.07) | 0.08 (0.06) | 0.844 |
| **Parent** | **MLU** | 4.31 (0.65) | 4.47 (0.64) | 0.041 | 4.31 (0.64) | 4.39 (0.67) | 0.479 | 4.31 (0.67) | 4.54 (0.60) | 0.023 |
| | **Types** | 14.62 (2.94) | 16.06 (3.47) | 0.000 | 14.04 (2.95) | 15.93 (3.30) | 0.000 | 15.20 (2.85) | 16.18 (3.67) | 0.048 |
| | **Tokens** | 73.67 (19.42) | 71.45 (17.38) | 0.240 | 70.70 (21.17) | 67.94 (18.10) | 0.277 | 76.56 (17.35) | 74.86 (16.16) | 0.551 |
| | **Questions** | 0.36 (0.08) | 0.42 (0.10) | 0.000 | 0.35 (0.08) | 0.40 (0.09) | 0.016 | 0.36 (0.08) | 0.45 (0.10)* | 0.001 |
| | **Conversations** | 1.03 (0.36) | 1.02 (0.31) | 0.723 | 0.97 (0.40) | 0.97 (0.40) | 0.980 | 1.10 (0.31) | 1.07 (0.27) | 0.610 |
| | **Turns** | 9.91 (3.14) | 10.86 (3.69) | 0.067 | 9.47 (3.45) | 11.07 (4.19) | 0.054 | 10.35 (2.78) | 10.66 (3.18) | 0.621 |

Note: MLU = Mean length of utterance in morphemes

*Denotes significant difference between Apps-only and Apps-with info group, $p<.05$

Table 3. *Partial correlations between duration of app use and visit 2 speech measures, controlling for visit 1 speech measures.*

| | | Total Duration of App Use |
|---|---|---|
| **Child** | **MLU** | 0.45*** |
| | **Types** | 0.11 |
| | **Tokens** | 0.14 |
| | **Questions** | 0.13 |
| **Parent** | **MLU** | -0.09 |
| | **Types** | -0.10 |
| | **Tokens** | -0.13 |
| | **Questions** | -0.10 |
| | **Conversations** | -0.04 |
| | **Turns** | -0.14 |

*** $p < 0.001$

Note: MLU = Mean length of utterance in morphemes

Table 4. *Results of fitting a taxonomy of multiple regression models predicting child MLU at visit 2*

| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 | Model 8 |
|---|---|---|---|---|---|---|---|---|
| MLU visit 1 | 0.51*** | 0.47*** | 0.48*** | 0.44*** | 0.48*** | 0.43*** | 0.47*** | 0.41*** |
| | (0.096) | (0.086) | (0.087) | (0.105) | (0.087) | (0.093) | (0.087) | (0.064) |
| Log of Total duration of app use | | 0.23*** | 0.24*** | 0.18** | 0.23*** | 0.21*** | 0.22*** | 0.18** |
| | | (0.051) | (0.054) | (0.060) | (0.051) | (0.053) | (0.052) | (0.111) |
| Parent Education | | | -0.02 | | | | | -0.03 |
| | | | (0.030) | | | | | (0.034) |
| QUILS | | | | 0.01 | | | | 0.01 |
| | | | | (0.006) | | | | (0.038) |
| Female | | | | | 0.10 | | | 0.04 |
| | | | | | (0.117) | | | (0.131) |
| Child Age | | | | | | 0.02 | | 0.02 |
| | | | | | | (0.013) | | (0.015) |
| Treatment | | | | | | | -0.10 | -0.08 |
| | | | | | | | (0.119) | (0.132) |
| _cons | 1.41 | -0.00 | 0.29 | -0.32 | -0.05 | -0.52 | 0.11 | -0.29 |
| | (0.249) | (0.383) | (0.526) | (0.601) | (0.390) | (0.546) | (0.407) | (0.821) |
| *N* | 75 | 75 | 75 | 68 | 75 | 75 | 75 | 68 |
| $R^2$ | 0.280 | 0.437 | 0.442 | 0.377 | 0.442 | 0.451 | 0.442 | 0.405 |

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: Cell entries are estimated regression coefficients and (standard errors).

Note: MLU = Mean length of utterance in morphemes

Table 5. *Partial correlations between the number of total videos viewed by the Apps-with-info families and visit 2 speech measures, controlling for visit 1 speech measures (n=38).*

| | | **Total videos viewed** |
|---|---|---|
| **Child** | **MLU** | 0.07 |
| | **Types** | 0.27 |
| | **Tokens** | 0.15 |
| | **Questions** | -0.01 |
| **Parent** | **MLU** | -0.02 |
| | **Types** | 0.41* |
| | **Tokens** | 0.16 |
| | **Questions** | 0.05 |
| | **Conversations** | 0.40* |
| | **Turns** | -0.25 |

* $p < 0.05$

Note: MLU = Mean length of utterance in morphemes

Photo Play


Story Mixer


Animal Antics


Figure 1. Sample images from the three apps: *Photo Play, Story Mixer, and Animal Antics.* The Photo Play sample shows a decorated photo with a prompt for parents to start a conversation. The Story Mixer sample shows the nursery rhyme with the mixed object a dyad created. The Animal Antics sample shows a scenario where dyads act out animals who need to share a toy.

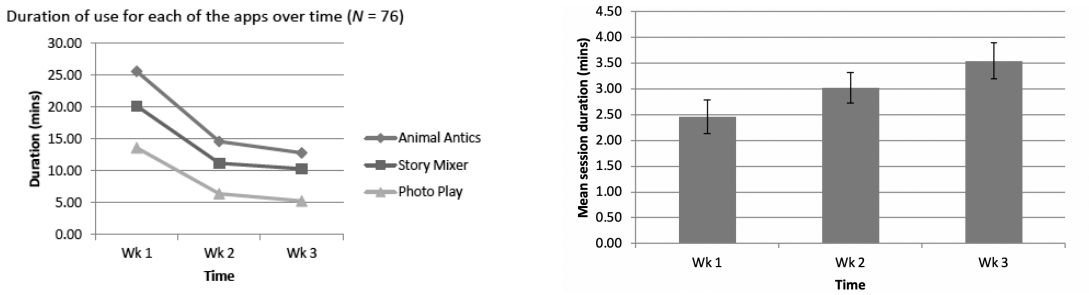


*Figure 2: Panel a (left) shows the duration of use for each of the apps over time and Panel b (right) shows the mean duration of each session of app use over time.*