Can 3-year-old children learn verbs using an educational touchscreen app?

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Research demonstrates that children can learn nouns using touchscreen apps, however there has been less attention to whether apps can also promote verb learning. In addition, only a few studies have investigated the role of adult-child co-use for facilitating language learning from touchscreen apps. In the present study, 3-year-old children were taught three novel verbs in a live condition or with an app. Children in the app condition either used the app in a child-led interaction or an adult-led interaction. Children's verb learning was assessed using a three-choice pointing task. Only children in the live condition showed evidence of verb learning and performed above chance, and there were no differences in performance by children in the app conditions. Children therefore did not show evidence of verb learning from our experimental app. Further research therefore needs to investigate different strategies for adult-child co-use and the role of different app features for supporting children's verb learning from apps.

Words: 158

Keywords: children, touchscreen apps, educational technology, word learning, verb learning, language

1.0 Introduction

Children's language development is an essential early skill related to children's socio-emotional development (Clegg, Law, Rush, Peters & Roulstone, 2015) and academic success (Fiorentino & Howe, 2004). Children's language development is strongly linked to the language they hear in their everyday environments both in terms of the quantity and the quality of the language experienced (Hart & Risley, 1995; Hoff & Naigles, 2002; Huttenlocher et al., 2010; Rowe, 2012; Weisleder & Fernald, 2013). For today's child, language development is both supported and hindered by digital technologies in their environment (Madigan et al., 2020; Kolak et al., 2023; Taylor et al., 2018). In this study, we investigate the conditions under which use of digital technology may provide an additional support to children's language development, in particular, in their acquisition of new vocabulary. Specifically, we test how verb learning may be supported by children using an app that they direct themselves versus using an app in co-use with an adult, and comparing learning from those situations with children learning the same words in a live interaction with an adult.

While educational digital technologies provide an opportunity to hear language that could support children's language development (Kolak et al., 2023), studies also demonstrate that parent media use may disrupt language development. Specifically, parent language is negatively impacted by the presence of background television (Christakis et al., 2009; Kirkorian, Pempek, Murphy, Schmidt, & Anderson, 2009; Pempek, Kirkorian, & Anderson, 2014), and mobile device use during parent-child interactions can disrupt word learning altogether (Reed et al., 2017). More recently a naturalistic study conducted in children's homes found a negative association between background television and parent-child interactions playing with a toy together and a positive association with infants' individual activities (Uzundağ et al., 2024).

In a meta-analysis, Madigan et al. (2020) found that while children's overall screen use - defined as time spent watching television, playing video games, using touchscreen devices or computers – was negatively related to their language scores, educational content and adult-child co-use was positively related to children's language scores. More recently, Jing et al. (2023) found a small positive correlation between children's digital media exposure and their vocabulary scores in experimental studies with educational media designed to support children's vocabulary learning. Thus, children's educational digital technology use has the potential to enrich a child's language development when used alongside other forms of interaction known to support language development (Taylor et al., 2018).

Children's touchscreen apps may be particularly well suited to supporting children's language development due to their interactive and contingent nature facilitating learning in a similar way to a social partner (see Kirkorian, 2018 for review). Apps with a learning goal targeting early skill development can also engage a child's attention and promote active learning and problem solving, provide specific feedback relating to a child's performance, scaffold the content to align with a child's performance on a given task (e.g., making a task more or less difficult) and expose children to a wide range of vocabulary (see Hirsh-Pasek et al., 2015; Kolak et al., 2021; Kolak et al., 2023 for similar arguments). Research shows that apps with a learning goal include more utterances including single and multi-word utterances, words with an earlier age of acquisition, and contain lower frequency words similar to books compared to apps without a learning goal (see Kolak et al., 2023; Taylor et al., 2022). Apps therefore have the potential to provide an enriched form of language input for young children.

Indeed, studies demonstrate that pre-school age children can learn new words from touchscreen apps (e.g., Ackermann et al., 2020; Arnold et al., 2021; Chiong & Shuler, 2010; Dore et al., 2019; Kirkorian et al., 2016; Russo-Johnson et al., 2017; Walter-Laager et al.,

2017). Dore et al. (2019) found that 4-year-olds could learn uncommon words (4 concrete nouns, 4 verbs and 2 abstract nouns) from an experimental app when tested immediately after using the app for just 10-12 minutes or after using the app once a week for four weeks in the classroom. Using the Khan Academy Kids app available in the app marketplace, Arnold et al. (2021) found that over a 10-week period 4- and 5-year-old children using the app for around 13 minutes per day showed subsequent gains in literacy skills.

However, research to date has primarily focussed either on broad gains in language skills (e.g., Arnold et al., 2021; Chiong & Shuler, 2010) or on children's ability to learn specific nouns from an app (e.g., Kirkorian et al., 2016; Russo-Johnson et al., 2017; Walter-Laager et al., 2017, with the exception of Dore et al., 2019). Word learning encompasses more than just acquisition of nouns, it is also important to consider other major classes of word type including children's ability to learn verbs, adjectives and adverbs. Although Dore et al. (2019) included exposure to 6 nouns and 4 verbs in their study, they did not distinguish between children's ability to learn the nouns and verbs from the touchscreen app. This is a particularly important question given that children learning the English language typically acquire nouns before verbs (Waxman et al., 2013, but note that this is not the case in other languages e.g. Tse et al., 2005). There are several reasons for this greater apparent difficulty in acquiring verbs. Verbs have less reliable contexts with other words in utterances than do nouns (Gleitman, 1990; Monaghan et al., 2015), meaning that distributional information for verbs is weaker than for nouns in English. In addition, verbs are conceptually less coherent than nouns, in that verb referents are dynamic and transient, whereas noun referents tend to be more stable within the child's environment (Childers & Tomasello, 2002; Gentner, 1982; Gillette et al., 1999), potentially requiring greater contextual information to support learning of verbs than nouns (e.g., Arunachalam & Waxman, 2011). Touchscreen apps may be advantageous for verb learning because they can display dynamic actions and provide a

useful environment where transience and ambiguity in verb reference can potentially be controlled. Thus, understanding how apps can promote verb learning is important for determining the full range of language support available from different kinds of exposure.

Another form of digital exposure is learning through interaction with an interlocutor through technology-mediated communication, such as video chats. Roseberry et al. (2009) found that 2.5-year-old children could learn verbs from a video only when the video was accompanied by a live adult imitating the actions, while 3-year-old children showed some evidence that they could learn verbs from video alone. In a follow up study, Roseberry et al. (2014) explored the role of social contingency in supporting 2.5-year-old children's verb learning from screens. 2.5-year-old children were shown novel actions labelled either during a live interaction, a socially contingent onscreen interaction (via Skype) or via a yoked video of the socially contingent onscreen interaction. The children learnt the novel verbs in the socially contingent conditions only and showed no evidence of learning if they saw the yoked video (Roseberry et al., 2014). Roseberry et al (2014) suggest that social contingency is important when learning from digital media to establish trust between the child and teacher, given that the researcher is able to respond accurately to the child's responses and cues. In a similar way, touchscreen apps may offer a form of contingency in response to children's touch, though digital contingency lacks the same social component present in Roseberry et al's research (2009; 2014). The contingency offered by touchscreen apps and their interactive nature may therefore be a help in supporting children's verb learning.

Along with the paucity of research on children's verb learning from touchscreen apps and other digital media, there have been few studies exploring the role of adult-child co-use on children's word learning from apps. The American Academy of Pediatrics (2016) recommend parent-child co-use during children's media use whereby parents interact with their children about the digital content. Consistent with this recommendation, a recent meta-

analysis with 17 eligible studies found a small but significant positive effect of co-viewing on children's learning across several learning domains (Taylor et al., 2024). Approximately half of the studies included in the meta-analysis included the experimenter as the adult-co-user, and the person co-using the digital media with children did not moderate the significant positive effect of co-viewing (Taylor et al., 2024). However, the majority of studies used video or television for the digital content (Taylor et al., 2024). Adult-child co-use can support children's learning through increasing children's attention to the digital content (Samudra et al., 2020). In their study, Samudra et al., (2020) found that 3- to 4-year-old children's comprehension of a video was associated with adult-child co-use, attention to the video and their language skills.

Adult-child co-use may be particularly beneficial for children's word learning given the social nature of children's language learning. For example, Strouse et al. (2018) found that 2.5-year-old children learnt more words from a socially contingent facetime video chat in a parent co-use condition compared to when the parent was engaged in another activity during the word learning task. In that study, parents were instructed to interact with the adult onscreen to set an example for their child rather than specifically directing the child's interaction with the onscreen actor. However, some research suggests that parents are less likely to engage with their children during children's app use compared to toy play, perhaps explained by apps requiring continuous attention and the fact that children spent the majority of their app use with the tablet on their lap (Hiniker et al., 2018). Indeed, Connell et al. (2015) found that approximately 64% of parents of 0–8-year-olds co-use touchscreen devices with their children "some of the time" or "all or most of the time". A systematic review by Ewin et al. (2021) found that parents engage in many forms of support during mobile device co-use such as interacting only when asked for help, supporting understanding and engagement with the content, and providing physical and technical support.

Understanding what constitutes effective parent-child co-use techniques to facilitate learning is also important since caregivers engage in various forms of co-use behaviours (Ewin et al., 2021). Neumann (2018) found that parents most frequently use cognitive scaffolding (e.g., helping children solve problems) to support 2-4-year-olds on a touchscreen rather than technical scaffolding (e.g., telling children how to use the app). In contrast, Griffith and Arnold (2019) found that parents talked more about the app (e.g., app features or how to interact with the app) compared to the apps' literacy and math content when using an app with their 4-year-olds. In relation to children's learning outcomes, Sheehan et al. (2019) found that parents' task relevant talk during a coding app was positively related to 4-year-old children's learning, while parents' questions were negatively related to children's learning. Importantly, these observational studies cannot reveal what aspects of adult-child co-use facilitate children's learning.

A couple of studies have started to investigate the role of parent-child app co-use on children's learning outcomes. In one study exploring whether co-use can improve children's ability to learn coding skills from an app (Griffith et al., 2022), 4- and 5-year-old children either played a coding app independently, with their parent, or played a colouring app with their parent. Overall, children who played the coding app showed an improvement in their coding skills compared to pre-test, with the greatest improvement in coding skills found for children who played the app with their parent rather than independently (Griffith et al., 2022). Similarly, Walter-Laager et al. (2017) found that 2-year-old children played with a touchscreen app for longer when using the app together with an adult compared to using the app independently. In addition, children who used the touchscreen app with an adult showed the greatest improvement in their knowledge of 12 nouns presented on the touchscreen app compared to children who used the app without an adult (Walter-Laager et al., 2017). Consistent with findings for parent-child co-use during video viewing (e.g., Strouse et al.,

193 2018), parent-child co-use during app use is beneficial for children's learning (Griffith et al.,
194 2022; Walter-Laager et al., 2017). Nevertheless, to date, no study has directly manipulated
195 co-use for children's touchscreen apps to explore the impact on verb learning, where the
196 dynamics of the referent and contextual information tend to be very different to those for
197 noun learning.

198 In the current study we asked whether children can learn verbs from touchscreen apps
199 under child-led or adult-led co-use conditions, and in a live condition. Three-year olds were
200 shown three novel verbs either on an app where the child led the app interaction or where the
201 experimenter led the app interaction, or in a live interaction with the experimenter. Each
202 novel verb was presented four times; twice in isolation and twice in intransitive sentences,
203 and children were given the opportunity to watch a video clip in which the action was
204 demonstrated. Verb learning was tested on the touchscreen tablet using a three-choice
205 pointing task using the same images from the app conditions. Given that Naigles et al. (2005)
206 showed that by 2 years of age, children can transfer novel verbs learnt in a live interaction to
207 videos, we hypothesised that children in the live condition would perform above chance on
208 the verb learning test. We therefore hypothesised that any difference in test performance
209 between the live and app conditions would result from differences in learning. Children under
210 the age of three years can only learn a novel verb from a video if it is supplemented with live
211 interaction (Roseberry et al., 2014, 2009). Thus, we hypothesised that children in the child-
212 led app condition would not show evidence of learning, while children in the adult-led app
213 condition would show evidence of learning. Note that the age we selected is at the cusp of
214 beginning to be able to learn verbs with and without social scaffolding (Roseberry et al.,
215 2009) and so potentially able to highlight distinctions between learning from apps versus live
216 interactions.

217

2.0 Method

2.1 Participants

A total of 29 36–48-month-old monolingual English language participants (*m* = 41.90 months, *SD* = 3.79) were included in data analysis. An additional 10 children were tested but excluded due to experimenter error (*n* = 5; 2 live condition, 2 adult-led condition, 1 child-led condition), child's refusal to complete the pointing task (*n* = 1, live condition), child's limited interaction with the app in the child-led condition (*n* = 1), bilingual (*n* = 1 child-led condition), and incomplete demographic information (*n* = 2 child-led condition). Ethical approval for the study was obtained from the University Research Ethics Committee at Lancaster University.

2.2 Stimuli

Four wooden objects were used for the live demonstrations (see Figure 1). Action verbs were selected from Childers and Tomasello (2002) and included *dacking* (spinning the object on a flat surface), *gorping* (putting the object on one's head) and *meeking* (holding the object up to the eye like a telescope).

Figure 1. Live demonstration objects

An app was created using an ABC format common to first words apps aimed at children. The app showed the letters D, G and M followed by four different images of children performing the action "dacking" after the letter D, "gorping" after the letter G and "meeking" after the letter M. In addition, three short videos were included which showed a

child performing each action (5-7 seconds in duration). When a picture was pressed, an abc "button" on the top right of the screen could be pressed so that an audio recording of the action label was played and the action word was written on the screen. The audio labels were played in the following order "D dacking", "the boy is dacking", "the girl is dacking", "D dacking" and followed the same sentence structure for each action word. In addition, a video icon in the top left of the screen could be pressed to play a video. The app was displayed on a Google Nexus 7 with a 7-inch screen.

2.3 Procedure

Children were tested at nurseries and in the lab. Prior to participating in the study, informed consent was obtained for nursery testing by sending parents an information sheet about the study along with the consent form and questionnaire or for lab testing by giving parents the paperwork upon their arrival to the lab. Children were randomly assigned to one of 3 conditions, an adult-led app condition (n = 12; mean age = 42.67, SD = 3.98), a child-led app condition (n = 7; mean age = 43.14, SD = 3.98), and a live condition (n = 10; mean age = 40.10, SD = 3.03). A one-way ANOVA confirmed that there were no significant differences in age between the three conditions ($F(2, 26) = 1.854$, $p = .177$).

All children engaged in a warm up interaction with the experimenter until a smile was elicited from the child. Following the warm up, the word learning session started (see Figure 2). All sessions were video recorded.

		Condition		
		Live	**Adult-led app**	**Child-led app**
Learning Trials	Verb exposure			
	1	Object 1 – action demonstration and label	Exemplar image and audio label	Demonstration of each functionality on the app followed by child free play

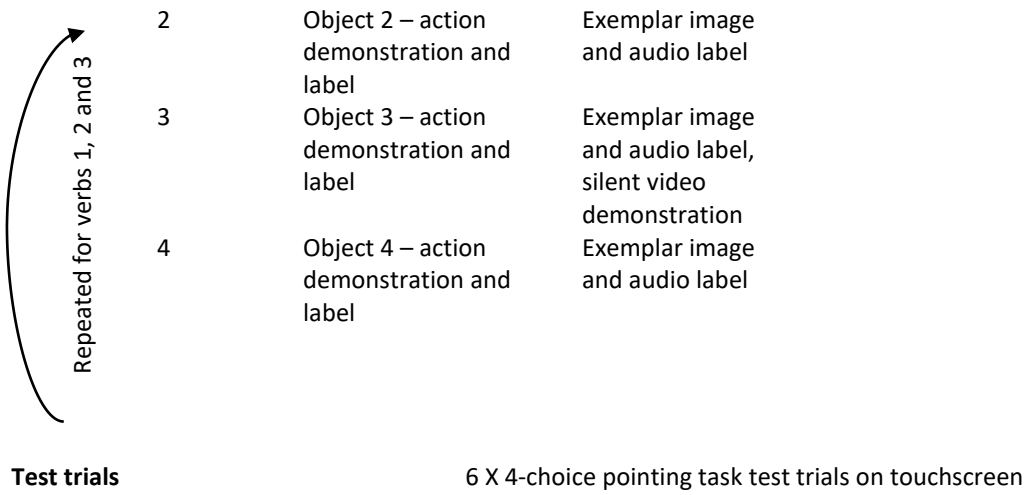

Figure 2. Diagram of the experimental design

2.3.1 Word learning session. Children in both the live and app conditions heard the novel action labels repeated four times in total.

For children in the adult-led app condition, the experimenter said "Do you want to see a fun app?". The experimenter then started the app and proceeded to click through the images in a systematic way. The experimenter let children see the home screen before clicking on the first picture of the action "dacking" and pressing the abc button to play the action label, the experimenter then swiped left to bring up the next picture followed by the abc button. For the third picture, the experimenter pressed the abc button and then the video button. Once the video had finished playing, the experimenter then swiped left again to show the final picture and pressed the abc button to play the action label. Once all of the "dacking" pictures had been shown, the experimenter clicked back onto the home screen and then started the same process for "gorping" and "meeking". Exposure to the app in this systematic way lasted approximately 2 ½ minutes.

For children in the child-led app condition, the experimenter said "I'm going to show you what these buttons do and then you can have a play with it. You can click on this (one

picture thumbnail), you can click on this (ABC-reveals word on the screen), you can click on this (video), and you can click on this (Babylab logo-home button). Now you can have a play." The child was then given the app to play with, and there was no interaction with the adult in terms of the app's content, similar to the distinction between the co-use and alone use of apps in Griffiths et al. (2022). If the child seemed discouraged to engage with the app, the experimenter would try to encourage them by stating the app was very fun and they would only have a play with it for a few minutes. Exposure to the app in this condition lasted approximately 5-6 minutes.

For children in the live condition, the experimenter said "I have some fun things to show you". The experimenter then brought out the first object and presented the "dacking" action while saying the action label, followed by demonstrating the action on the second object while saying "I'm dacking", the third object while saying "I'm dacking" and then demonstrating action on the fourth object saying "dacking". The same process followed for the "gorping" and "meeking" actions using the same objects in the same order and the same sentence structure for the action labels in the same order. After each action demonstration the object was placed out of sight so that only one object was visible at a time. The live demonstrations lasted approximately 2 minutes.

2.3.2 Word learning test. Children participated in a three-choice pointing task (method adapted from Twomey, Ranson, & Horst, 2014) for the word learning test. For the pointing task, images were presented on the touchscreen tablet and the test images were taken from the verb learning app. The pictures were therefore familiar to children in the app conditions but novel to children in the live condition. Children were given three warm up practice trials in which the experimenter asked the child to point to one of three pictures depicting familiar actions in succession (sleeping, drinking, sliding) and provided feedback on children's responses (e.g., "That's right", "Well done!"). The practice trials were

followed by six test trials in which the experimenter asked the child to point to pictures of each of the novel actions labelled in the word learning session twice. The experimenter did not provide feedback during the test trials. The order in which the novel object labels were asked for and the quadrant for each image were counterbalanced across conditions using a Latin square design.

2.4 Scoring

Approximately 20% (n = 6) of the video recordings were double coded by an independent observer. Inter-observer reliability analysis was 94% (kappa = .883). For the pointing task, children were given a score of 0 (wrong) or 1 (correct) for each of the six pointing trials. A mean score was then calculated across the six trials to give children a pointing task score. Preliminary analysis revealed no significant effect of gender or test word order on word learning scores, and the data was therefore collapsed across gender and word order.

3.0 Results

The learning accuracy for all three groups is shown in Table 1. We conducted one sample t-tests to determine whether performance was better than chance (0.33) for each condition, also shown in Table 1. The live condition resulted in significant learning, but the app conditions did not show learning better than chance.

Table 1. Accuracy for the three conditions, comparisons against chance level.

Condition	Mean	SD	n	t	*p*	*d*
Live	0.58	0.27	10	2.91	.017	0.92
Adult-led App	0.33	0.22	12	0.05	.960	0.01
Child-led App	0.43	0.25	7	1.04	.341	0.39

In order to compare performance across the conditions, we next conducted generalised linear mixed effects (GLME) model analyses on accuracy of children's responses during the test phase. In the model we used Helmert coding to determine whether there was a difference in learning from live interaction compared to either type of app (learning material format), where the live condition was coded as 1, and each app condition was coded as -0.5. A significant positive effect would indicate that the live condition was advantageous for learning compared to the apps. We also used Helmert coding to determine whether there was a difference between the two types of app (app interaction condition: child-led or adult-led), with the child-led app coded as 1, and the adult-led app coded as -1 (and the live condition coded as 0 so that it did not contribute to this factor). A significant positive effect would indicate that the child-led app resulted in better learning than the adult-led app. We included participant as a random effect, but also including which word was being tested as a random effect resulted in a singular fit, so this was omitted. The model failed to converge when learning material format or app interaction condition were included as random slopes, so only a random intercept was included.

We first constructed a null model which contained only random effects, then we added in the fixed effects one at a time, using log-likelihood comparisons to determine whether each fixed effect contributed significantly to model fit (Barr et al., 2013).

Adding learning material format as a fixed effect significantly improved model fit, $\chi^2(1) = 4.49$, $p = .026$. Adding app interaction condition (adult-led, child-led) did not significantly improve model fit, $\chi^2(1) = 0.74$, $p = .389$, and so this was not included in the final model. The final model is shown in Table 2.

Table 2. Final GLME model of learning accuracy from live compared to app interactions.

	Estimate	SE	z	*p*
Intercept	-0.398	.214	-1.862	.063
Learning material format	0.774	.345	2.244	.025

174 observations, 29 participants.

R syntax: glmer(Accuracy ~ ApporLive + (1|ParticipantID), data = data, family = binomial)

The results show, that children learned significantly better from live interactions than either app condition, and that there was no significant difference between the effectiveness of the two app interaction conditions used in this study. Further, the results confirmed that learning was not effective for either app condition in this study with participants in those conditions not performing above chance.

3.1 Post Hoc Power Analyses

For the effect of whether the condition was live or the app, the effect size was 0.77. Post hoc power analyses (using powerSim and mixedpower Monte Carlo simulations, Kumle et al., 2021) yielded estimated power = .65, 95% CI = (.62, .68). Simulations with different sample sizes indicated that, in a future study, 45 participants would be needed for power = .80, and more than 60 participants would be needed for power to exceed .90. However, we also calculated a Bayes Factor to determine whether there was evidence for the experimental hypothesis of a difference between live and use of the app compared to the null hypothesis (that there would be no difference). There was moderate evidence for there being a difference

between conditions, $BF_{HN}(0, 0.40) = 5.26$ (Lee & Wagenmakers, 2014), indicating that the sample was sufficient to produce evidence for the distinction.

For the effect of whether the app was designed for children or not, the effect size was small at 0.22. Post hoc power analysis indicated power = .16, 95% CI = (.13, .18) for detecting this effect as significant. Simulations indicated that a study would require 325 participants in order to reach power > .80. Thus, because app design has a small effect on learning, app design would require a large number of participants to find a significant difference in learning in a future study. Bayes Factor calculations reflected that there was no evidence for either the experimental hypothesis of there being a difference between conditions, nor of evidence for there being no difference, $BF_{HN}(0, 0.35) = 1.14$.

4.0 Discussion

In the present study, 3-year-old children successfully learnt novel verbs as demonstrated by above chance performance in pointing at static pictures of the verbs in the live condition but not in the app conditions. This finding is particularly striking because children in the live condition had to transfer the verb learnt in a live context to a previously unseen static 2D image of the verb on the touchscreen tablet (see also Naigles et al., 2005 for verb learning transfer ability). For children in the app conditions, the static images used during the test session were also used in the learning phase and should have been more familiar to those children. Thus, despite the potentially easier transfer from training to test, children showed no evidence of learning novel verbs from our experimental app, in contrast to the literature demonstrating that children can learn novel nouns from apps effectively (e.g., Kirkorian et al., 2016; Russo-Johnson et al., 2017). The current study thus demonstrates that there was sufficient referential information present in the situation for children to acquire the

verbs (e.g., repetitions of the novel action and verb), but that the mode of delivery of this information had consequences for whether the verb was learned.

Our use of two conditions to deliver the app content to children enabled us to test various conditions under which verbs could be learned by children. Children in both the adult-led and child-led app conditions did not perform above chance in the learning test. For children in the child-led app condition, this finding contrasts with previous research demonstrating that children can learn new words (primarily nouns) from touchscreens when using touchscreen apps independently (e.g., Dore et al., 2019; Kirkorian et al., 2016; Russo-Johnson et al., 2017; Walter-Laager et al., 2017). However, our finding is consistent with studies on children's verb learning from video in which children required additional live social interaction to support their learning (Roseberry et al., 2014, 2009) which was not present to the same degree in our adult-led app condition which focussed on systematically showing children the app content rather than providing interactions about the app content. Thus, we had hypothesised that children in the adult-led app condition would show evidence of verb learning but our findings do not support this hypothesis. This may have been because of the relatively fixed way in which co-use was determined in our study. In the co-use condition, the adult showed the child the functionality of the app, and operated the app. In Griffiths et al. (2022) for instance, the child operated the app with the adult alongside. The agency of the use, and the contingency of responses by the adult, therefore may have influenced the differences in learning in our study compared to Griffiths et al. (2022), though in their case the app was around developing programming rather than language skills.

Importantly, there are a number of different strategies that can be employed for adult-child co-use when children use touchscreen apps together (see Griffith & Arnold, 2019; Neumann, 2018; Sheehan et al., 2019). In our study, an unfamiliar adult showed the child each of the app features in a systematic way and the child did not interact with the app during

the word learning session, similar to our live condition in which the child was not allowed to interact with the toys during the word learning session. Prior work has shown that this strategy can support 2.5- and 3-year-olds when learning to imitate specific actions to make a puzzle on a touchscreen (Zimmermann et al., 2017). However, this strategy might not be helpful for supporting children's verb learning from touchscreens. Furthermore, in their observational study, Griffith and Arnold (2019) found that caregivers held the tablet 38% of the time and interacted with the touchscreen 20% of the time. A purely adult-led method of parent-child co-use is therefore uncommon during naturalistic interactions with touchscreens and may have disrupted children's learning. Moreover, parent-child co-use interactions during media use in studies are typically not scripted and may be beneficial in supporting children's learning, though no moderator effect of the adult co-using digital media with children has been found (Taylor et al., 2024).

Verb learning from our app may have been impoverished due to the timing of the verb label or the number of exemplars provided by the app. Children in the app conditions saw a dynamic video of each action only once without a verbal label, and verbal labels were provided alongside a static picture of the action before and after the dynamic video. In contrast, children in the live condition saw four dynamic demonstrations of the action with the verb labelled during the action demonstration. Given that motion information is inherent in verbs, motion information may be necessary when learning novel verbs (Kersten & Smith, 2002). In addition, children in the app conditions saw static images of four novel actors and novel objects for each verb (sixteen novel objects and actors in total for the three novel verbs). In contrast, children in the live condition saw the same actor across all verb demonstrations and the same four novel objects for each action (one novel actor and four novel objects in total for the three novel verbs). Prior work has shown that multiple exemplars during learning can hinder children's ability to extend verbs to a novel actor

(Maguire, Hirsh-Pasek, Golinkoff, & Brandone, 2008) and children attend to object information when learning novel verbs with novel objects (Kersten & Smith, 2002). Therefore, the app conditions may have provided children with too many exemplars of the verb action, or children need motion information to learn verbs.

Equally, it is also possible that verb learning from our touchscreen app was hindered by the quality of our app. Studies investigating word learning from touchscreen apps differ significantly in terms of app design from apps designed for experimental purposes (Dore et al., 2019; Kirkorian et al., 2016; Russo-Johnson et al., 2017) to commercially available apps (Walter-Laager et al., 2017). Dore et al., (2019) based their app design on the four pillars framework (Hirsh-Pasek et al., 2015) and therefore the app was designed to support learning based on cognitive theory and the science of learning. In contrast, experimental apps typically have simple designs, for example, requiring children to touch the screen to play a video of an adult opening a box and labelling the object inside (Kirkorian et al., 2016) or a narrator labelling a single object on the screen followed by the ability for children to tap or drag the object to move it across the river (Russo-Johnson et al., 2017). Our experimental app was based on a commercially available app, and evaluating our experimental app using Kolak et al., (2021)'s app evaluation questionnaire which is based on theories of children's cognitive development and learning from digital media, suggests that our app would score just 6/20 in terms of educational potential. Indicating that the commercially available app on which our app was based is also unlikely to support children's learning is consistent with prior studies investigating the educational potential of commercially available children's touchscreen apps in the app marketplace (Kolak et al., 2021; Meyer et al., 2021; Taylor et al., 2022).

Children's touchscreen apps have the potential to enrich a child's language input and support their language development (see Kolak et al., 2023; Taylor et al., 2022). Although research to date has started to explore what makes an app educational for young children and

how to support children's noun learning from apps, understanding how touchscreen apps could support other forms of word learning (e.g., verbs, adjectives, adverbs) or areas of language development (e.g., syntax) remains under researched. While our study starts to address a gap in the literature by investigating children's verb learning from touchscreen apps, our study is limited in three ways. First, the sample size is small, and although it was sufficient to detect a difference between the live and app conditions, if there are (much) smaller differences between child- and adult-led conditions then these were not possible to observe in the current study. Second, the study is limited by its inability to tease apart whether the effects we observed were specific to verb compared to noun learning, or whether the observed difference between live compared to app use conditions were due to the particular constraints of the app that we had designed. Future work could directly compare verb and noun learning from a well-designed educational app. Doing so will help us understand whether adult-child co-use and specific app features are necessary to support verb learning from children's apps. Third, the study was restricted to learning intransitive verbs. Though this is in line with many previous studies of verb learning (e.g., Childers & Tomasello, 2002; Monaghan et al., 2015; Srinivasan et al., 2017), extending the research to address how both transitive and intransitive verbs are acquired is an important aim for future research (Childers et al., 2023).

5.0 Conclusion

In conclusion, we investigated the conditions under which children might be able to learn novel verbs from technology, comparing how 3-year-old children learn from live interaction varied from using an app with an adult versus using an app alone. We found that the children in our study did not show evidence of verb learning from a touchscreen app regardless of whether the child or the adult led the app interaction, although they did show learning of the same verbs from a live interaction. Nevertheless, we encourage future work to

484 consider how touchscreen apps could support children's language development beyond noun
485 word learning and consider the role of different app features for supporting verb learning.
486 Furthermore, research should start to systematically explore optimal strategies for adult-child
487 co-use when using touchscreen apps to support children's language development.

488

Conflict of interest

The authors declare no conflict of interest.

Author Contributions

GT: Conceptualisation, Methodology, Investigation, Data Curation, Writing – Original Draft. PM: Methodology, Formal analysis, Writing - Review & Editing, Supervision. GW: Methodology, Writing - Review & Editing.

Funding

This research was supported in part, by the ESRC International Centre for Language and Communicative Development (LuCiD; ES/L008955/1) and an Early Career Small Grant from Lancaster University.

Acknowledgments

The authors would like to thank all the children who participated in this project and Ana Morales for assisting with data collection.

Data Availability Statement

The data for this study is available at:
https://osf.io/cdn4m/?view_only=e7b464fb6056487484024b7533b12f7e

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