Research Report

January 2022

Enhancing Literacy Outcomes with *Duolingo ABC*

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Abstract

This formative study investigates whether the use of *Duolingo ABC*, a digital app designed to support young children's emergent literacy skills, improves children's literacy outcomes. The study used a single sample pre-test/post-test design with 105 4-5-year-old children and their caregivers. Results of regression analyses indicated that after using the app for 9 weeks, children's literacy skills were significantly higher at the end of the study as compared to baseline, as measured by the PALS-K. The number of hours children spent using the *Duolingo ABC* app significantly predicted the post-test outcome when controlling for caregiver education, number of books in the home, days in Kindergarten, and pre-test scores. Post-test scores on children's interest in and motivation for reading, as well as confidence in reading, were all significantly higher than pre-test scores after 9 weeks of access to the app. The results of this study yield promising evidence that the *Duolingo ABC* app may support young children in learning to read and building fluency. These findings will inform ongoing development of *Duolingo ABC*.

Introduction

Learning to read is a key milestone for children and involves several component skills and processes. The Common Core Standards call out four foundational skills: (1) print concepts, (2) phonological awareness, (3) phonics and word recognition, and (4) fluency. These skills are the stepping stones to developing proficient readers. Specifically, the Common Core states that these skills are "*directed toward fostering students' understanding and working knowledge of concepts of print, the alphabetic principle, and other basic conventions of the English writing system*" (Common Core State Standards, 2010). The National Early Literacy Panel (Lonigan & Shanihan, 2009) points to similar skills, highlighting conventional reading skills such as alphabet knowledge and phonological awareness, as well as cognitive processing skills, that typically develop from birth to age five. These early literacy and language skills are strong predictors of future reading and writing ability (Lonigan & Shanihan, 2009; Neumann, 2020) and academic success (Duncan et al., 2007; Zimmerman et al., 2008). However, more than one in three American children enter Kindergarten without the skills they need to learn to read (Council on Early Childhood, 2014). As such, young children must be provided with high-quality, impactful learning experiences that foster early literacy.

As more young children interact and engage with technology, digital formats have become increasingly important contexts for learning. Research has shown that 98% of homes with children under eight years old own a device (Rideout & Robb, 2020). In addition, during the COVID-19 pandemic, young children are spending even more time using digital devices (Johnson, 2021). This time spent with technology provides an opportunity to engage young children with meaningful and educational digital learning experiences. Like tablets and smartphones, mobile devices offer anytime, anywhere learning moments. Recent research suggests that young children can learn early literacy concepts and skills fostered through digital media and games (Griffith et al., 2021; Kennedy et al., 2021; Marsh, 2016; Neumann & Neumann, 2017). For example, children (ages 2–5) using an iPad-based literacy app displayed significantly higher letter name and sound knowledge, print concepts, and name writing skills than those in the control group after only nine weeks (Neumann, 2018). Research also suggests that when students' learning needs are considered, literacy software can support students' acquisition of skills (Connor, 2019; Rogowsky et al., 2017; Xie et al., 2018).

Language exposure for young children, digital and non-digital, happens primarily at home and school; as such, caregivers play a critical role in children's learning. Joint media engagement is the practice of people sharing media experiences (Takeuchi & Stevens, 2011), and research suggests that when caregivers get involved using digital media, not only does the child learn but the caregiver learns as well (Clark, 2011; Pasnik et al., 2015; Rasmussen et al., 2016; Strouse et al., 2013). Previous research has also suggested that joint media engagement may help children build on their existing literacy skills (Neumann, 2018; Takeuchi & Stevens, 2011; Wood et al., 2016). Therefore, caregivers can enhance the quality of learning for young children by scaffolding children's digital interactions to help build their early literacy and language skills.

About *Duolingo ABC*

Duolingo ABC was designed to provide an engaging and educational early literacy curriculum to early readers. The app targets key components of reading identified by the National Reading Panel (2000), including 1) *alphabetics*, 2) *phonological awareness*, 3) *phonics and decoding*, 4) *fluency*, 5) *vocabulary*, and 6) *comprehension*. Understanding how *Duolingo ABC* might impact young children's literacy learning will help improve the digital early-learning space and provide insights as to how *Duolingo ABC* is being used by children and their caregivers.

Research Methods

The purpose of this formative study was to assess the value of the *Duolingo ABC* app in supporting children's early literacy skills, and use the results to further improve the design and development of the app. The study was designed to answer the following research questions:

1. Is 9 weeks of access to *Duolingo ABC* positively associated with preschool children's early literacy skills, including alphabet awareness, phonological awareness, and word recognition?

    a. To what extent does time spent with the app (dosage) account for variation in children's learning outcomes?
    b. To what extent does parental co-engagement account for variation in children's learning outcomes?

2. Is 9 weeks of access to *Duolingo ABC* positively associated with children's interest in and motivation for reading?

3. Is 9 weeks of access to *Duolingo ABC* positively associated with children's confidence in reading?

Design

This study used a single sample pre-test/post-test design. Researchers assessed children's literacy abilities before and immediately following the 9-week study period. The details of the design are included below.

Recruitment

Researchers recruited caregivers[1] through social media and direct outreach to preschool partners from May through July 2021. Interested participants completed a screener questionnaire to determine eligibility. The screening process prioritized children between the ages of 4.0–5.5 years who did not begin Kindergarten before September 2021.[2] All children were beginning readers by parent/guardian report, such that they were not proficient on multiple target reading skills. All children and at least one parent/guardian were required to be English-proficient, although they could have a non-English home language. Caregivers were required to have an iOS device (iPhone or iPad only) regularly available to the child and internet access for study participation because the app was only available on iOS at the time of the study. "Regular availability" of the iOS device meant that the child would have individual access to the device for at least one hour per week. Children who had IEPs or other special needs were excluded from this formative study; future work with larger samples would be needed to detect differences in outcomes for these children.

A power analysis using G*Power3 with standard assumptions (α = .05, power = .80), testing five predictors (e.g., pre-test score, dosage, caregiver engagement, age, and preschool attendance), indicated we would minimally be able to detect an effect size of .14 with a sample size of 100 children.[3] As such, we aimed to enroll 115 children to

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[1] The term caregiver is used throughout to represent parents or other primary guardians of the children that participated in the study.

[2] Because the *Duolingo ABC* app has a digital Kindergarten literacy curriculum, the sample prioritized children ages 4.0–5.5 years and those who started Kindergarten after September 1, 2021. Prioritizing this age group and minimal overlap with Kindergarten helped to increase the chances that effect sizes would be associated with the app rather than Kindergarten instruction.

[3] Kraft (2020) suggests an effect size of .17 based on longer literacy interventions. A conservative effect size of .14 is comparable to the effects observed in other studies by the authors for similar interventions.

have appropriate power for the proposed analyses. Children were required to complete the baseline literacy assessment to continue the study.

Two-hundred and seventy-five (275) caregivers were invited to participate in the study based on their initial response to the interest form. Of those invited, 149 caregivers completed the initial survey. Forty-four (44) caregivers did not complete the study for various reasons, leading to a 29.5% attrition rate. One hundred and five (105) caregivers completed the pre-test measures, 103 caregivers completed the post-survey, and 96 completed the entire study. Therefore, analyses using survey data are based on the 103 caregivers that completed pre-post measures. In contrast, analyses on literacy outcomes are based on the sample of 96 for whom we have complete pre-and post-test data. A summary of attrition can be found in Table A2 in the Appendix.

Participants

Participants were a national sample of 105 children within the target age range for *Duolingo ABC* and their caregivers ($M = 58.39$ months, $SD = 3.95$). Sixty-two percent of the sample was female. Sixty-one percent of the sample identified as white, 10 percent Black, 10 percent Latinx or Hispanic, 4 percent Asian, and 15 percent as two or more races (Figure 1). Ninety-one percent of caregivers reported speaking only English at home, with 9 percent speaking a combination of English and Spanish or another language.

Most children were in homes with adults who held at least a 4-year college degree: 43 percent of participating caregivers reported holding a graduate degree, 33 percent a bachelor's degree, and 3 percent an associate's degree. Sixteen percent reported completing some college but no degree and 5 percent completed a high school degree or equivalent. Forty-six percent of participating caregivers reported $100,000 or more in annual income (Figure 2). Demographics were similar between caregivers that completed the study and those that did not. The total number of books in the home for participants was approximately normally distributed, with 32 percent reporting 101-200 books. Tables A3-A12 in the Appendix present the full range of participant demographics.

Figure 1
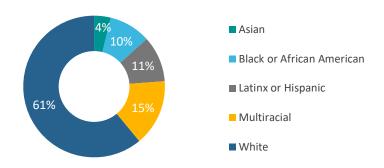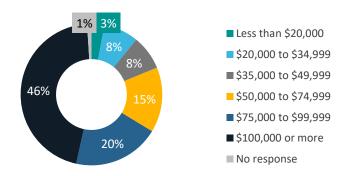*Participants By Child Race/Ethnicity (N = 105)*

Color	Category	Percent
■	Asian	4%
■	Black or African American	10%
■	Latinx or Hispanic	11%
■	Multiracial	15%
■	White	61%

Figure 2
Participants By Household Income (N = 105)

Color	Category	Percent
■	Less than $20,000	3%
■	$20,000 to $34,999	8%
■	$35,000 to $49,999	8%
■	$50,000 to $74,999	15%
■	$75,000 to $99,999	20%
■	$100,000 or more	46%
■	No response	1%

Intervention

The intervention/exposure period to the *Duolingo ABC* app lasted approximately nine weeks for participating children (*M* = 65.77 days, *SD* = .47). The research team recommended that children use *Duolingo ABC* at least one hour each week. Based on prior research on other literacy interventions, this dosage level was likely to achieve learning gains for the skills emphasized in the app (e.g., Kennedy et al., 2021; Neumann, 2018). The intervention was home-based and used the technology families already had at home (i.e., iPhone or iPad). Participants accessed the most recent experimental build of the app via a private server. The research team provided limited technical support to caregivers if they had difficulties accessing the app during the intervention period.

Procedures

Eligible participants were directed to a scheduling system to complete a pre-survey. This survey collected demographic characteristics, the number of books families had at home (a proxy measure for parental engagement around reading), and baseline parent-report measures of the child's interest in and motivation for reading as well as confidence in reading. At the end of the survey, caregivers were sent to a scheduling system to set up their first video conference meeting.

During this first meeting, researchers obtained consent, administered the pre-test assessment, and then oriented caregivers to the *Duolingo ABC* app. After a brief warmup and child assent, assessors administered the Phonological Awareness Literacy Screening-Kindergarten (PALS-K; Form B), using digital stimuli presented via screen share and recorded children's answers via paper scoresheets. As noted above, researchers recommended that the child use *Duolingo ABC* at least an hour per week; one possible usage scenario, recommended by *Duolingo ABC* researchers, was to spend 15-20 minutes 3-4 times a week[4]. These recommendations were intended to be informative rather than prescriptive; natural variation in use was expected. Caregivers were encouraged to interact with their children during app use during this time. The research team sent weekly text messages to participating caregivers as a reminder to use the app.

Throughout the 9-week intervention period, analytics of engagement were collected via the app by Duolingo and shared with the research team at the end of the study period. After the intervention period, the child was assessed again via video conference using the alternate form of the PALS-K (Form A). Caregivers completed another survey to collect post-measures of the parent/guardian report outcomes and some items to gather formative feedback on the app based on their experiences during the study. At the end of the study, caregivers were compensated for their time.

Measures

The study included pre-and post-assessments of children's early literacy skills. Baseline measures were used in analyses to control for children's knowledge and skill levels before using the app. Parent measures included a survey to collect demographic characteristics and parent-report measures to assess their children's interest in and

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[4] This guidance was based on a recommendation from the app developers as a useful guideline for caregivers on how long a typical session might last.

motivation for reading as well as confidence in reading. Measures for this study are described in greater detail below.

PALS-K. The PALS-K assesses several dimensions of children's early literacy skills, including rhyme awareness, beginning sound awareness, lower-case alphabet recognition, beginning letter sounds, spelling, and concept of word. The PALS-K has robust validation and reliability evidence and demonstrates excellent psychometrics across grade, gender, socioeconomic status, and race/ethnicity (Invernizzi et al., 2009); the PALS-K has been used effectively in remote administration, a key reason for its selection. Alternate forms were used at pre- and post-test to mitigate the potential for learning effects or priming. To avoid ceiling effects, an optional subtask, word recognition in isolation, was added at the post-test for children who scored 5 or higher on the concept of word task. For the remotely administered version of the PALS-K, instructions and questions are read out loud by the assessor, as they would be in person, while digital stimuli are displayed to the child via screen share. Children's answers are recorded on paper scoresheets, as they would be in person.

Parent surveys. Pre- and post-survey questions helped provide context for the ways caregivers use *Duolingo ABC* and their broader literacy practices. Children's interest in and motivation for reading were measured using a section of the Caregivers Digital Literacy Questionnaire (Ozturk & Ohi, 2018). Researchers used measures of literacy behaviors (Smith & Dixon, 1995) to create a measure of early signs of confidence in reading. As this is an unvalidated measure, these data are treated as exploratory. Caregivers were also asked to report on their children's engagement in certain literacy activities post-intervention.

Engagement. Children's use of *Duolingo ABC* was measured using back-end usage tracking data and reported as cumulative hours spent on learning exercises over the 9-week intervention period. Parent-child joint engagement was measured by taking this variable (cumulative hours spent using the app) and using a multiplier based on parent/guardian report of co-engagement on the post-intervention survey (Never = 0; Seldom = .2; Occasionally = .4; Weekly = .6; Daily = .8).

Analytic Approach
The research team conducted descriptive analyses of quantitative data from the literacy assessment, survey measures, and engagement analytics. Responses to continuous variables are summarized using means and standard deviations; frequency tables are used for discrete measures.

To answer RQ1 and RQ2, investigating app exposure and its association with children's outcomes (i.e., literacy skills, interest in and motivation for reading) from pre- to post-intervention, the research team conducted multiple regression analyses on post-test scores, with pre-intervention scores used as baseline measures. Correlations of key participant-level variables (e.g., gender, preschool attendance) with the outcome variable were examined; a variable was included as a covariate if it was correlated with the outcome at $p < .10$.[5]

To investigate RQ1a, the dosage measure was entered separately into the final model from the previous step; dosage was measured as the cumulative number of hours spent using the app. To investigate RQ1b, a measure of joint engagement (e.g., number of hours parent/guardian and child spent using the app together) was entered separately into the final model from the previous step.

To address RQ2, similar regression analyses explored children's interest in and motivation for reading, as measured by parent/guardian report, controlling for baseline interest and motivation and other covariates correlated with the outcome at $p < .10$.

To answer RQ3, regression analyses were again used to explore children's confidence in reading, using the adapted measure and again controlling for baseline confidence and other covariates correlated with the outcome at $p < .10$.

All analyses have been designed to meet Every Student Succeeds Act's (ESSA) Tier 3 level of evidence (US Department of Education, 2016). This guidance was designed to help states, districts, schools, and educators select interventions based on evidence that they will improve outcomes for students. Tier 3 is classified as Promising Evidence that uses a correlational design with statistical controls for selection bias on the intervention.

Results

Results from parent-report survey data collected prior to the intervention suggest that participating caregivers often engaged in literacy practices at home even before the study began. Before the intervention, 72.4% of caregivers reported reading to their children daily. The majority of caregivers (53.3%) reported spending between 11 and 20

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[5] Our purpose in selecting the $p < .10$ threshold was to establish transparent and straightforward guidelines for our decision making in advance of seeing the data and follows Heinze et al. (2018). This ensures that covariates are neither included nor excluded based on any favorable impact on our findings.

minutes when they read to their children. Seventy-three (73.3) percent of caregivers reported that their child looks through books or other printed materials daily. Eighty-eight percent (87.6) reported that, when they sit down to read, their child is the one to select the book. All of these measures were similar at post-test. See tables A13-A23 for details on parent/guardian reports of literacy activities at home.

On the pre-survey, caregivers also reported levels of children's technology use and, in particular, engagement with educational apps. Forty-six (45.7) percent reported less than one hour per day of child engagement with a phone, tablet, computer, or console, and 27.6% reported between one to two hours. Regarding educational app usage, 28.6% reported no use by their child daily, and 52.4% reported less than an hour of usage per day. Tables A23 and A24 report details on technology use.

On the post-survey, caregivers reported how their child accessed the *Duolingo ABC* app during the intervention period. Sixty-two (62.1) percent reported that their child used an iPhone to use the app, and 35.9% reported using an iPad. Only 1.9% reported use of both devices. Sixty-three (63.1) percent reported that the primary device used for the study belonged to an adult in the family, and the child used it for accessing the app. Tables A25 and A26 report how children accessed the *Duolingo ABC* app during the study.

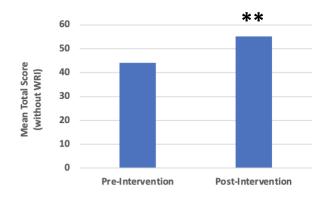The main findings of interest are presented by research question below.

Is 9 weeks of access to *Duolingo ABC* positively associated with preschool children's early literacy skills, including alphabet awareness, phonological awareness, and word recognition?

A set of demographic and educational context variables were tested for associations with the PALS-K post-test outcome measure. These variables were as follows: child age, child gender, child race/ethnicity, home language; parent/guardian education, household income, number of books in the home, child's months spent in preschool, child's number of days spent in Kindergarten, and number of days spent with the *Duolingo ABC* app during the intervention period. Variables that were correlated at $p <$ .10 with post-test scores were parent/guardian education ($r = .27$, $p = .007$), household income ($r = .28$, $p = .006$), days in Kindergarten ($r = .18$, $p = .075$), and number of books in the home ($r = .30$, $p = .003$). Household income was dropped from the model because one family did not report their income. In addition, household income was

significantly correlated with parent/guardian education at $r = .56$, $p < .001$, with some signs of multicollinearity.

Multiple linear regression was used to test whether PALS-K pre-test scores significantly predicted PALS-K post-test scores. The final fitted regression model was PALS-Kpost = 15.00 + 1.05 (PALS-Kpre) - .16 (ParentEducation) - .79 (Books in Home) - .03 (DaysK). The overall regression was statistically significant ($R^2 = 0.85$, $F(4, 95) = 129.12$, $p < .001$). It was found that PALS-K post-test scores were significantly higher than pre-test scores ($B = 0.94$, $t = 20.24$, $p < .001$) when controlling for caregiver education, number of books in the home, and days in Kindergarten (Figure 3). This finding was extremely robust and held regardless of the covariates included in or excluded from the model. The PALS-K benchmarks (see Table 1) demonstrate an anticipated growth of roughly 6 points per month over the course of the Kindergarten school year; the pre-K children using *Duolingo ABC* in this study demonstrated approximately the same rate of growth (6 points per month) over the 9-week intervention.

Figure 3
PALS-K Pre-Test Scores Significantly Predicted the Post-Test Outcome (n = 96)

Note: ** $p < .001$

Each subscore of the PALS-K was also examined, using the same covariates from the final model for the post-test total score. Each post-test subscore was significantly higher than the pre-test subscore at the $p < .001$ level. See Table 1 for a summary of scores

and subscores at pre-test and post-test, along with the typical benchmarks for children in Kindergarten (slightly older than the study sample).

Table 1
Mean PALS-K Scores and Subscores at Pre-Test and Post-Test, With Kindergarten Benchmarks

Score/Subscore	Pre-test Mean (*SD*)	Post-test Mean (*SD*)	K Benchmarks		
			Fall	Midyear	Spring
Total Score	43.02 (*25.55*)	55.21 (*24.37*)**	29	-	83
Rhyme Awareness (Individual)	6.82 (*3.14*)	7.46 (*2.81*)**	5	9-10	9
Beginning Sound Awareness (Individual)	4.94 (*3.34*)	6.58 (*3.22*)**	5	9-10	9
Lower-case Letter Recognition	15.18 (*8.07*)	18.05 (*6.72*)**	12	23-26	24
Letter Sound Recognition	10.41 (*8.44*)	14.00 (*7.59*)**	5	17-26	21
Spelling	4.82 (*5.43*)	7.69 (*6.42*)**	2	10-20	13
Concept of Word (partial)	0.85 (*1.73*)	1.43 (*2.51*)**	0	3-10	7

Note: *N* = 105 at pre-test; *n* = 96 at post-test, ** *p* < .001

Caregivers also responded to a question on the post-survey about their children's literacy behaviors, "After using the *Duolingo ABC* app, have you noticed any of the following in your child's behavior? (Select all that apply)." The largest percentage of caregivers (62.9%) reported an increase in their child identifying the first sound of spoken words or noting words that rhyme. At least 30 percent of caregivers also reported seeing increases in their child identifying letters, "letter teams," or words on a page (38.1%); writing words or sentences independently or pretending to write (36.2%); asking questions about the meaning of words, sentences, and stories (35.2%); and reading independently or pretending to read (31.4%). The percentage of caregivers selecting each option is reported in Table 2.

Table 2

Responses to Parent Survey Item on Changes in Literacy Behaviors (n = 103)

Literacy Behavior	*n*	Percent
An increase in identifying the first sound of spoken words ("milk" starts with "m") or noticing words that rhyme	66	62.9%
An increase in identifying letters, "letter teams," and/or words on a page	40	38.1%
An increase in writing words or sentences independently or pretending to write	38	36.2%
An increase in asking questions about the meaning of words, sentences, and stories	37	35.2%
An increase in reading independently or pretending to read (books, signs, labels, etc.)	33	31.4%
An increase in retelling stories in their own words	26	24.8%
An increased ability to learn new vocabulary from stories and illustrations	20	19.0%
An increase in understanding stories that are read aloud	20	19.0%
An increase in predicting what will happen in a story	20	19.0%
None of the above	15	14.3%

Note: Percentages do not total 100% because caregivers could choose more than one option.

To what extent does time spent with the app (dosage) account for variation in children's learning outcomes?
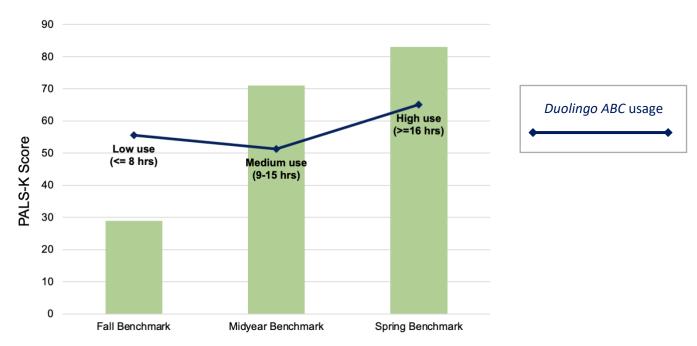
On average, children spent 13.15 hours (*SD* = 10.06) on learning exercises within the app, with a range from 0 to 68 hours.[6] The average days of usage obtained by children (with a possible 69 over 9 weeks) was 23.41 (*SD* = 14.52). To assess an average level of difficulty children may have experienced, we also calculated the percentage of learning exercises on which children made at least one error (4.26%, *SD* = 2.56). Table A28 in the Appendix provides descriptive statistics on the dosage and use measures.

The cumulative hours spent on learning exercises, the construct representing dosage, was added into the regression model from RQ1 in a separate step. The final fitted regression model was PALS-Kpost = 10.79 + 1.04 (PALS-Kpre) - .19 (ParentEducation) - .66 (Books in Home) - .01 (DaysK) + .32 (Hours). The overall regression was statistically significant (R^2 = 0.86, F(5, 95) = 112.64, $p < .001$). It was found that number

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[6] Only one child did not use the app over the course of the study.

of hours spent using the *Duolingo ABC* app significantly predicted the post-test outcome (B= 0.11, t = 2.80, p = .006) when controlling for caregiver education, number of books in the home, days in Kindergarten, and pre-test. At post-test, high-frequency users of *Duolingo ABC* scored close to the midyear Kindergarten benchmark score (see Figure 4). It is interesting to note that the relationship between time using the app and outcome doesn't appear to be linear. This might be an artifact of the current sample, the measure of usage, or some other factor that was not measured. Further research with a larger sample might be able to tease apart these possible explanations.

Figure 4
PALS-K Scores for Low-, Medium-, and High-Frequency Users, as Compared to Kindergarten Benchmarks (n = 96)

To what extent does parental engagement account for variation in children's learning outcomes?

On the five-point joint engagement item estimating how often caregivers spent interacting with their children on the app, 21.0% of caregivers reported jointly engaging daily, 28.6% weekly, 30.5% occasionally, 13.3% seldom, and 4.8% reported never jointly engaging with the app. When multiplied with the cumulative hours of use variable, this resulted in an average of 7.15 hours (*SD* = 7.07), ranging from 0 and 40.80 hours of
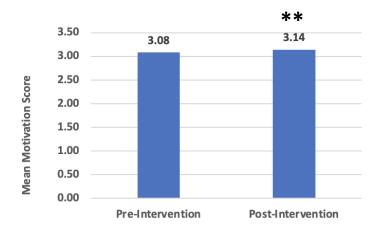
joint engagement during the 9-week intervention. This term for joint engagement was added into the regression model from RQ1 in a separate step. The final fitted regression model was PALS-Kpost = 13.52 + 1.05 (PALS-Kpre) - .27 (ParentEducation) - .76 (Books in Home) - .02 (DaysK) + .26 (JointHours). The overall regression was statistically significant (R^2 = 0.85, $F(5, 95)$ = 105.48, $p < .001$). However, the number of hours of joint engagement with the *Duolingo ABC* app did not significantly predict the post-test outcome (B= 0.06, $t = 1.58$, $p = .12$) when controlling for caregiver education, the number of books in the home, days in Kindergarten, and pre-test.

Is 9 weeks of access to *Duolingo ABC* positively associated with children's interest in and motivation for reading?

The same set of demographic and educational context variables were tested for associations with the interest and motivation post-test outcome measure. Variables that were correlated at $p < .10$ with post-test scores were race/ethnicity ($r = .17$, $p = .086$), parent/guardian education ($r = .27$, $p = .006$), number of books in the home ($r = .43$, $p < .001$), and PALS-K pre-test score ($r = .30$, $p = .002$).

Multiple linear regression was used to test whether the parent-report interest and motivation scores significantly predicted post-test interest and motivation scores. The final fitted regression model was InterestMotivationpost = .42 + .71 (InterestMotivationpre) + .03 (Race/Ethnicity) + .01 (ParentEducation) + .10 (Books in Home) + .00 (PALS-Kpre). The overall regression was statistically significant (R^2 = 0.67, $F(5, 102)$ = 39.49, $p < .001$). It was found that pre-test interest and motivation scores significantly predicted the post-test outcome ($B = 0.74$, $t = 11.60$, $p < .001$) when controlling for race/ethnicity, parent/guardian education, number of books in the home, and PALS-K pre-test score (see Figure 5). Frequencies and percentages for parent-report of children's interest in and motivation for reading, both pre and post, are reported in tables A29 and A30 respectively in the Appendix.

Figure 5

Pre-Test Interest In and Motivation for Reading Scores Significantly Predicted the Post-Test Outcome (n = 103)
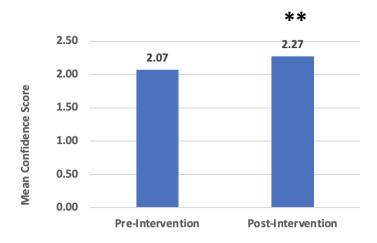

Note: ** $p < .001$

Is 9 weeks of access to *Duolingo ABC* positively associated with children's confidence in reading?

Consistent with previous methodology, the same set of demographic and educational context variables were tested for associations with the post-test confidence in reading outcome measure. Variables that were correlated at $p < .10$ with post-test scores were English as a home language ($r = .26$, $p = .008$), number of books in the home ($r = .25$, $p = .01$), days spent attending Kindergarten ($r = .17$, $p = .087$), and PALS-K pre-test score ($r = .26$, $p = .007$).

Multiple linear regression was used to test whether the parent-report confidence in reading scores significantly predicted post-test confidence in reading scores. The final fitted regression model was Confidencepost = -0.33 + 0.51 (Confidencepre) +1.25 (English) + 0.03 (Books in Home) + 0.01 (DaysK) + 0.00 (PALS-Kpre). The overall regression was statistically significant ($R^2 = 0.42$, $F(5, 101) = 13.98$, $p < .001$). It was found that pre-test confidence in reading scores significantly predicted the post-test outcome ($B = 0.51$, $t = 5.99$, $p < .001$) when controlling for English as a home language, number of books in the home, days spent attending Kindergarten, and PALS-K pre-test score (Figure 6). Frequencies and percentages for parent-report of children's confidence in reading, both pre and post, are reported in tables A31 and A32, respectively.

Figure 6

Pre-Test Confidence in Reading Scores Significantly Predicted the Post-Test Outcome (n = 103)

Note: ** *p* < .001

Discussion

The central conjecture for this study was that the *Duolingo ABC* app, when experienced by children over a significant period of exposure, would support higher early literacy skills, interest, and confidence. A discussion of the major findings around this conjecture follows.

Literacy Skills

We found consistent and robust gains across research questions. With respect to our primary research question regarding literacy skills, we found that 9 weeks of access to *Duolingo ABC* – even with instructions to use the app for only an hour a week – resulted in significant increases at post-test. Unsurprisingly, we found that caregiver education, days in Kindergarten, and the number of books in the child's home were also significantly correlated with post-test scores, although only the pre-test score was significant in the final model. Children's time spent in pre-Kindergarten was not significantly related to the post-test score and thus not included as a covariate. This result is unsurprising as we would expect pre-K attendance to be more associated with children's pre-test performance on PALS-K.

This significant pre-versus-post finding held for the total score and each of the subscores (rhyme awareness, beginning sound awareness, lower-case letter recognition, letter sounds, spelling, and concept of word). In Table 1, we include the benchmarks for PALS-K on sub-scores at Kindergarten entry and mid-year (approximately February-March of Kindergarten year) to show the expected growth over 4-5 months of Kindergarten. This provides a high-range approximation of the growth we might expect to see over the 9 weeks of the intervention.

Duolingo ABC App Dosage

Children's post-test PALS-K scores were also significantly and positively related to the amount of time children spent with the app. The more time children spent with *Duolingo ABC*, the better they did at post-test. The measure that was used for dosage was summed from the back-end data from children's time spent on learning exercises. This measure likely represents a solid estimate for time spent on-task learning and was likely to exclude the majority of the time where the app may have been left idle before locking the device or time spent navigating the app in its menu.

Parent Engagement

While the construct created for caregiver engagement was not significant in our model, a robust body of literature supports the benefits of parent-child interaction during learning with educational apps in this age group (e.g., Bassok et al., 2016; Skwarchuk et al., 2014; Strouse et al., 2013). It is possible that the measure that was used here to represent caregiver engagement was too imprecise to capture nuances in engagement. Additional research could be conducted using more precise diary measures of engagement. The phrasing of the question used here (joint engagement during app usage) might also have impacted our findings. It is quite possible that, rather than engagement during app usage, interaction with children prior to or after app use to reinforce the skills and practices they have learned might be equally or more critical.

Children's Interest in and Motivation for and Confidence in Reading

Both models testing for positive associations between use of the app and parent-report of children's interest in and motivation for reading, as well as confidence in reading, were significant, suggesting that, in addition to supporting skill development, the app may also be supporting the development of positive attitudes towards reading. While the interest and motivation measure developed by Ozturk & Ohi (2018) has been previously validated, the measures used for measuring caregiver reports of children's confidence in reading were adapted, as no similar validated measure was found. Future research is needed to further investigate these attitudes in preschool children, either with new

validated parent-report measures or, ideally, data directly from children. However, the results from this study serve as exploratory evidence of promise on these outcomes.

Conclusion

Taken together, the findings from this study suggest that *Duolingo ABC* holds promise for engaging preschool children in activities that support the development of key emergent literacy skills. Further, the app may provide experiences that support children's development of positive attitudes toward reading and self-efficacy in using their literacy skills. Significant increases in all of these outcomes were observed after 9 weeks with the app. Further, high-frequency users during the intervention period had the highest average scores on the PALS-K, as compared to low- or medium-frequency users.

This study has several limitations. First, while our design used a pre-post testing paradigm, we did not use an experimental design with random assignment to a treatment condition (e.g., either app exposure or no exposure). As such, the methods limit our ability to attribute causality between *Duolingo ABC* exposure and the positive associations reported in this investigation. Second, it is important to note that the sample was skewed in several ways that may influence the findings. The participating sample of children was not equally balanced by gender, with more females than males. Participating caregivers were largely white, English-speaking, college-educated, and made more than $75,000 in annual income. Requirements were placed on caregivers to participate in the study that may have influenced participation (e.g., having access to an iPhone or iPad, reliable internet access). Third, several measures used to assess children's interest in and motivation for reading as well as confidence in reading were based on caregiver reports. Children were not observed by researchers; as such, results should be interpreted with the caution that caregivers may have a positive bias in reporting attitudes in their children. Finally, this study was conducted during the COVID-19 pandemic, which might have impacted the ways in which children and families engaged with the app.

The results described here set the stage for future research into how *Duolingo ABC* may support literacy learning in children. An investigation using an experimental design would support the development of causal inferences between *Duolingo ABC* and the improvement in outcomes observed here. Second, more research is needed to test the associations found in this research with broader populations to generalize to other groups beyond the current sample. Finally, the relationship between app usage and

PALS-K outcome did not appear to be linear; further research might help identify whether that was an artifact of the current sample, the way that usage was measured, or some other factor that was beyond the scope of this formative work.

References

Bassok, D., Lee, R., Reardon, S.F., & Waldfogel, F. (2016). Socioeconomic gaps in early childhood experiences, 1998 to 2010. *AERA Open*, *2*(3), 1–22. https://doi.org/10.1177/2332858416653924

Clark, L. S. (2011). Parental mediation theory for the digital age. *Communication Theory*, *21*(4), 323-343. https://doi.org/10.1111/j.1468-2885.2011.01391.x

Connor, C. M. (2019). Using technology and assessment to personalize instruction: Preventing reading problems. *Prevention Science*, *20*, 89-99. https://doi.org/10.1007/s11121-017-0842-9

Council on Early Childhood. (2014). Literacy promotion: An essential component of primary care pediatric practice. *Pediatrics*, *134*(2), 404-409. https://doi.org/10.1542/peds.2014-1384

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., Pagani, L. S., Feinstein, L., Engel, M., Brooks-Gunn, J., Sexton, H., Duckworth, K., & Japel, C. (2007). School readiness and later achievement. *Developmental Psychology, 43*(6), 1428-1446. https://doi.org/10.1037/0012-1649.43.6.1428

Griffith, S. F., Hagan, M. B., Heymann, P., Heflin, B. H., & Bagner DM (2020). Apps as learning tools: A systematic review. *Pediatrics*, *145*(1). https://doi.org/10.1542/peds.2019-1579

Heinze, G., Wallisch, C., & Dunkler, D. (2018). Variable selection - A review and recommendations for the practicing statistician. *Biometrical journal. Biometrische Zeitschrift*, *60*(3), 431–449. https://doi.org/10.1002/bimj.201700067

Invernizzi, M., Juel, C., Swank, L., & Meier, J. (2009). *PALS K Technical Reference.* University of Virginia. https://palsresource.info/wp-content/uploads/2015/03/ktechnical_ref.pdf

Johnson, J. (2021, January 27). *US kids & teens with 4hrs+ screen time before and during COVID-19 pandemic 2020.* Statista.

Kennedy, J. L., Christiensen, C., Maxon, T., Gerard, S., Garcia, E., Kook, J., Hupert, N., Vahey, P., & Pasnik, S. (re-submission). The efficacy of digital media resources in

improving children's ability to use informational text: An evaluation of *Molly of Denali* from PBS KIDS. *American Educational Research Journal*.

Kraft, M. A. (2020). Interpreting effect sizes of education interventions. *Educational Researcher*, *49*(4), 241–253. https://doi.org/10.3102/0013189X20912798

Lonigan, C., & Shanahan, T.. (2009). Developing early literacy: Report of the National Early Literacy Panel. Executive summary. A scientific synthesis of early literacy development and implications for intervention. National Institute for Literacy.

Marsh, J. (2016). The digital literacy skills and competencies of children of preschool age. *Media Education*, *7*(2), 178-195.

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common Core State Standards for English language arts and literacy in history/social studies, science, and technical subjects*. Washington, DC: Authors. http://www.corestandards.org/wp-content/uploads/ELA_Standards1.pdf

National Reading Panel (U.S.) & National Institute of Child Health and Human Development (U.S.). (2000). *Report of the National Reading Panel: Teaching children to read: an evidence-based assessment of the scientific research literature on reading and its implications for reading instruction*. U.S. Dept. of Health and Human Services, Public Health Service, National Institutes of Health, National Institute of Child Health and Human Development.

Neumann, M. (2018). Using tablets and apps to enhance emergent literacy skills in young children. *Early Childhood Research Quarterly*, *42*, 239-246. https://doi.org/10.1016/j.ecresq.2017.10.006

Neumann, M. M. (2020). The impact of tablets and apps on language development. *Childhood Education*, *96*(6), 70-74. https://doi.org/10.1080/00094056.2020.1846394

Neumann, M. M., & Neumann, D. L. (2017). The use of touchscreen tablets at home and preschool to foster emergent literacy. *Journal of Early Childhood Literacy*, *17*(2), 203-220. https://doi.org/10.1177/1468798415619773

Ozturk, G., & Ohi, S. (2018). Understanding young children's attitudes towards reading in relation to their digital literacy activities at home. *Journal of Early Childhood Research*, *16*(4), 393-406. https://doi.org/10.1177/1476718X18792684

Pasnik, S., Moorthy, S., Llorente, C., Hupert, N., Dominguez, X., & Silander, M. (2015). *Supporting parent-child experiences with* PEG+CAT *early math concepts: Report to the CPB-PBS Ready to Learn Initiative*. Education Development Center & SRI International.

Rasmussen, E. E., Shafer, A., Colwell, M. J., White, S., Punyanunt-Carter, N., Densley, R. L., & Wright, H. (2016). Relation between active mediation, exposure to *Daniel Tiger's Neighborhood*, and US preschoolers' social and emotional development. *Journal of Children and Media*, *10*(4), 443–461. https://doi.org/10.1080/17482798.2016.1203806

Rideout, V. & Robb, M. B. (2020). *The Common Sense census: Media use by kids age zero to eight, 2020*. Common Sense Media.

Rogowsky, B. A., Terwilliger, C. C., Young, C. A., & Kribbs, E. E. (2018). Playful learning with technology: The effect of computer-assisted instruction on literacy and numeracy skills of preschoolers. *International Journal of Play*, *7*(1), 60–80. http://dx.doi.org/10.1080/21594937.2017.1348324

Skwarchuk, S.-L., Sowinski, C., & Lefevre, J.-A. (2014). Formal and informal home learning activities in relation to children's early numeracy and literacy skills: The development of a home numeracy model. *Journal of Experimental Child Psychology*, *121*, 63–84. https://doi.org/10.1016/j.jecp.2013.11.006

Smith, S. S., & Dixon, R. G. (1995). Literacy concepts of low- and middle-class four-year-olds entering preschool. *The Journal of Educational Research, 88*(4), 243-253. https://doi.org/10.1080/00220671.1995.9941305

Strouse, G. A., O'Doherty, K., & Troseth, G. L. (2013). Effective co-viewing: Preschoolers' learning from video after a dialogic questioning intervention. *Developmental Psychology*, *49*(12), 2368–2382. https://doi.org/10.1037/a0032463

Takeuchi, L., & Stevens, R. (2011). *The new co-viewing: Designing for learning through joint media engagement*. New York: The Joan Ganz Cooney Center at Sesame Workshop. https://www.joanganzcooneycenter.org/wp-content/uploads/2011/12/jgc_coviewing_desktop.pdf

US Department of Education. (2016). Non-Regulatory Guidance: Using Evidence to Strengthen Education Investments.

Wood, E., Petkovski, M., De Pasquale, D., Gottardo, A., Evans, M. A., & Savage, R. S. (2016). Parent scaffolding of young children when engaged with mobile technology. *Frontiers in Psychology*, *7*, 690-690. https://doi.org/10.3389/fpsyg.2016.00690

Xie, H., Peng, J., Qin, M., Huang, X., Tian, F., & Zhou, Z. (2018). Can touchscreen devices be used to facilitate young children's learning? A meta-analysis of touchscreen learning effect. *Frontiers in Psychology*, *9*, 2580. https://doi.org/10.3389/fpsyg.2018.02580

Zimmerman, S. S., Rodriguez, M. C., Rewey, K. L., & Heidemann, S. L. (2008). The impact of an early literacy initiative on the long-term academic success of diverse students. *Journal of Education for Students Placed at Risk*, *13*(4), 452-481. https://doi.org/10.1080/10824660802427744

Appendix

Table A1
Kindergarten Start Dates

Kindergarten status and overlap between kindergarten start dates and the study period	Number	Percent of children
Children who did not begin Kindergarten in 2021	72 children	69.9%
Children who began Kindergarten in August 2021	9 children	8.7%
Children who began Kindergarten in September or October 2021	22 children	21.4%
Total	103 children	100%
Days[a] between Meeting 1 and Kindergarten start dates for children who began Kindergarten in 2021		
Average number of days	33 days	–
Minimum number of days	3 days	–
Maximum number of days	79 days	–
Number of days since Kindergarten began and the day of participating in Meeting 2 with a researcher		
Average number of days	32 days	–
Minimum number of days	0 days	–
Maximum number of days	60 days	–

[a]Note: The number of days represents seven days a week as opposed to days of instruction.

Table A2
Caregiver Attrition Status

Caregiver status	Number of caregivers
Active throughout the study	**96**
Invited to participate in the study based on responses to the interest form	275
Completed pre-study survey	149
Completed pre-study survey and Meeting 1 with researcher	105
Completed post-study survey	103
Completed post-test assessment	96
Reasons for attrition	
Attrition: Did not complete pre-study survey	126
Attrition: Did not attend Meeting 1 with researcher	14
Attrition: Did not attend Meeting 2 with researcher	3
Attrition: Parent withdrew	9
Attrition: Did not have a device to access *Duolingo ABC*	7
Attrition: Started the pre-test but did not complete	6
Attrition: Started the post-test but did not complete	4
Attrition: Child age	2
Attrition: Other*	8

Note: "Other" attrition reasons included caregivers not scheduling Meeting 1 and caregiver experiencing scheduling conflicts with the window in which Meeting 1 or 2 were offered.

Table A3

Child Gender

Child gender	Number of caregivers	Percent of caregivers
Children whose caregivers completed pre-study survey[7]		
Female	65	61.9%
Male	40	38.1%
Non-binary	0	0%
Total active	105	100.0%
Children whose caregivers were inactive after pre-study survey		
Female	27	60.0%
Male	18	40.0%
Non-binary	0	0%
Total	45	100.0%

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[7] In tables A3–A10, comparisons are drawn between children whose caregivers completed the pre-study survey (as well as Meeting 1 with a researcher) and children whose caregivers did not continue in the study after the pre-study survey. The authors present demographic information for all who completed the pre-study survey to be comprehensive. Of particular interest was whether those children whose caregivers did not continue on with the study after the pre-study survey had any similar characteristics to one another or to those who did continue on in the study.

Table A4

Child Race/Ethnicity

Child race/ethnicity	Number of caregivers	Percent of caregivers
Children whose caregivers completed pre-study survey		
Asian	4	3.8%
Black or African American	10	9.5%
Latinx or Hispanic	11	10.5%
Two or more races	16	15.2%
White	64	61.0%
Total	105	100.0%
Children whose caregivers were inactive after pre-study survey		
Asian	2	4.4%
Black or African American	6	13.3%
Latinx or Hispanic	1	2.2%
Two or more races	5	11.1%
White	31	68.9%
Total	45	100.0%

Table A5

Languages Spoken at Home

Languages spoken at home	Number of caregivers	Percent of caregivers
Caregivers who completed pre-study survey		
English only	96	91.4%
English and Spanish	4	3.8%
English and language other than Spanish	4	3.8%
Other language(s)	1	1.0%
Total	105	100.0%
Children whose caregivers were inactive after pre-study survey		
English only	43	95.6%
English and Spanish	1	2.2%
English and language other than Spanish	1	2.2%
Other language(s)	0	0.0%
Total	45	100.0%

Table A6

Highest Level of School or Highest Degree Completed by Caregivers

Highest level of school or highest degree completed by parents	Number of caregivers	Percent of caregivers
Caregivers who completed pre-study survey		
Less than a high school degree	0	0.0%
High school degree or equivalent	5	4.8%
Some college but no degree	17	16.2%
Associate degree	3	2.9%
Bachelor's degree	35	33.3%
Graduate degree	45	42.9%
Total	105	100.0%
Caregivers were inactive after pre-study survey		
Less than a high school degree	0	0.0%
High school degree or equivalent	3	6.7%
Some college but no degree	8	17.8%
Associate degree	2	4%
Bachelor's degree	14	31%
Graduate degree	16	36%
No response	2	4%
Total	45	100.0%

Table A7
Household Income

Household income	Number of caregivers	Percent of caregivers
Caregivers who completed pre-study survey		
Less than $20,000	3	2.9%
$20,000 to $34,999	8	7.6%
$35,000 to $49,999	8	7.6%
$50,000 to $74,999	16	15.2%
$75,000 to $99,999	21	20.0%
$100,000 or more	48	45.7%
No response	1	1.0%
Total active	105	100.0%
Children whose caregivers were inactive after pre-study survey		
Less than $20,000	2	4.4%
$20,000 to $34,999	4	8.9%
$35,000 to $49,999	4	8.9%
$50,000 to $74,999	5	11.1%
$75,000 to $99,999	7	15.6%
$100,000 or more	21	46.7%
No response	2	4.4%
Total inactive	45	100.0%

Table A8

Number of People in the Household

	Number of people in the household
Caregivers who completed pre-study survey (*N* = 105)	
Mean	4.46
Standard deviation	1.08
Median	4
Minimum	2
Maximum	8
Caregivers inactive after pre-study survey (*n* = 42)	
Mean	4.07
Standard deviation	1.30
Median	4
Minimum	2
Maximum	8

Table A9

Number of Children Age 17 Or Younger in the Household

Number of children in the household	Number of caregivers	Percent of caregivers
Caregivers who completed pre-study survey		
One child	12	11.4%
Two children	50	47.6%
Three children	26	24.8%
Four children	9	8.6%
Five children	4	3.8%
Six children	0	0.0%
No response	4	3.8%
Total active	105	100.0%
Caregivers inactive after pre-study survey		
One child	8	17.8%
Two children	18	40.0%
Three children	4	8.9%
Four children	2	4.4%
Five children	0	0.0%
Six children	1	2.2%
No response	12	26.7%
Total inactive	45	100%

Table A10

Number of Children Age 17 or Younger in the Household

	Number of children in the household
Caregivers who completed pre-study survey (*n* = 101)	
Mean	2.44
Standard deviation	0.95
Median	2
Minimum	1
Maximum	5
Caregivers inactive after pre-study survey (*n* = 33)	
Mean	2.12
Standard deviation	1.05
Median	2
Minimum	1
Maximum	6

Table A11

Number of Child Participants Who Attended Preschool (N = 105)

Preschool Attendance	Frequency (%)
Did not attend preschool	38 (36.2%)
Attended preschool	67 (63.8%)
Average number of months in preschool	15.86 months
Minimum number of months in preschool	3 months
Maximum number of months in preschool	36 months

Table A12
Number of Children's Books in the Household (N = 105)

Number of Books	Number of caregivers	Percent of caregivers
1 to 10 books	6	5.7%
11 to 50 books	16	15.2%
51 to 100 books	22	21.0%
101 to 250 books	34	32.4%
251 to 500 books	19	18.1%
More than 500 books	8	7.6%
Total	105	100.0%

Table A13
How Often Someone in the Household Reads to the Child

Source and *n*	Seldom Freq. (%)	Occasionally Freq. (%)	Weekly Freq. (%)	Daily Freq. (%)
Pre-Study Survey (*N* = 105)	2 (1.9%)	10 (9.5%)	17 (16.2%)	76 (72.4%)
Post-Study Survey (*n* = 103)	1 (1.0%)	10 (9.7%)	14 (13.6%)	78 (75.7%)

Table A14
How Long Someone Reads to the Child

Source and *n*	1 to 10 minutes Freq. (%)	11 to 20 minutes Freq. (%)	21 to 30 minutes Freq. (%)	Longer than 30 minutes Freq. (%)
Pre-Study Survey (*N* = 105)	22 (21.0%)	56 (53.3%)	22 (21.0%)	5 (4.8%)
Post-Study Survey (*n* = 103)	20 (19.4%)	54 (52.4%)	24 (23.3%)	5 (4.9%)

Table A15
How Often the Child Looks through Books and Other Printed Materials

Source and *n*	Seldom Freq. (%)	Occasionally Freq. (%)	Weekly Freq. (%)	Daily Freq. (%)
Pre-Study Survey (*N* = 105)	3 (2.9%)	12 (11.4%)	13 (12.4%)	77 (73.3%)
Post-Study Survey (*n* = 103)	1 (0.97%)	11 (10.7%)	15 (14.6%)	76 (73.8%)

Table A16
How Much Time the Child Spends Looking through Books and Other Printed Materials

Source and *n*	1 to 10 minutes Freq. (%)	11 to 20 minutes Freq. (%)	21 to 30 minutes Freq. (%)	Longer than 30 minutes Freq. (%)
Pre-Study Survey (*N* = 105)	35 (33.3%)	50 (47.6%)	15 (14.3%)	5 (4.8%)
Post-Study Survey (*n* = 103)	37 (35.9%)	42 (40.8%)	17 (16.5%)	7 (6.8%)

Table A17
Survey Question: Location of Child and Reader

Source and *n*	Usually sits beside the reader so your child can see the story	Usually sits across from the reader so your child can hear the story	Other*
Pre-Study Survey (*N* = 105)	94 (89.5%)	3 (2.9%)	8 (7.6%)
Post-Study Survey (*n* = 102)	95 (93.1%)	1 (0.98%)	6 (5.9%)

*Note: Six caregivers reported that the child usually sits in the reader's lap on the pre-study survey. Two caregivers who selected "Other" did not provide an explanation. Four caregivers reported that the child usually sits on the reader's lap on the post-study survey. One caregiver reported that their child could read independently. One caregiver reported that it varies.

Table A18

Who Holds the Book and Turns the Pages when Child Is Read to

Source and *n*	Your child holds the book and turns the pages	You (or someone) hold the book and turn the pages	Other*
Pre-Study Survey (*N* = 105)	15 (14.3%)	78 (74.3%)	12 (11.4%)
Post-Study Survey (*n* = 102)	16 (15.7%)	73 (71.6%)	13 (12.7%)

*Note: On the pre-study survey, four caregivers reported that both they and their child hold the book and turn the pages. Seven caregivers reported that they hold the book, and the child turns the pages. One caregiver who reported "Other" did not provide an explanation. On the post-study survey, six caregivers reported that both approaches were used. Seven caregivers reported that they hold the book, and the child turns the pages.

Table A19

Who Selects the Book or Story

Source and *n*	Your child usually selects the book or story	You (or someone) usually selects the book or story	Other*
Pre-Study Survey (*N* = 105)	92 (87.6%)	3 (2.9%)	10 (9.5%)
Post-Study Survey (*n* = 103)	95 (92.2%)	2 (1.9%)	6 (5.8%)

*Note: On the pre-study survey, ten caregivers reported that both they and the child select books or stories. On the post-study survey, six caregivers reported that they and the child select books or stories.

Table A20

Beliefs about Reading to Child

Source and *n*	I believe that reading to my child will help them learn to read	I believe that reading to my child is not likely to help them learn to read	Other*
Pre-Study Survey (*N* = 105)	103 (98.0%)	0 (0.0%)	2 (1.9%)
Post-Study Survey (*n* = 103)	102 (99.0%)	0 (0.0%)	1 (1.0%)

*Note: On the pre-study survey, one caregiver reported that they are unsure, and one caregiver reported that reading to their child will help them love books and have a big imagination. On the post-study survey, one caregiver reported that reading to their child would help them think about the story and context.

Table A21

Survey Question: Do you or someone else do any literacy instruction with your child in the home? (N = 105)

Response	Freq. (%)
Yes	55 (52.4%)
No	50 (47.6%)

Table A22

Types of Literacy Instruction in the Home Outside of Duolingo ABC (N = 105)

Type of Instruction in the Home	Yes Freq. (%)	No Freq. (%)
Phonics or literacy apps	30 (28.6%)	75 (71.4%)
Educational videos	20 (19.0%)	85 (81.0%)
Used materials sent home from preschool	16 (15.2%)	89 (84.8%)
Other	32 (30.5%)	73 (69.5%)

Table A23

Behaviors Likely to Occur When Caregivers Read to their Children

Reading Behavior	Pre-Study Survey $N = 105$ Freq. (%)	Post-Study Survey $n = 103$ Freq. (%)
I frequently stop reading and point out objects for my child to identify in the pictures.	67 (63.8%)	70 (68.0%)
I frequently stop reading and point out letters in the print.	34 (32.4%)	32 (31.1%)
I frequently stop reading and point out pictures that illustrate what was told in the story.	73 (69.5%)	69 (67.0%)
I frequently stop reading and ask what will happen next?	42 (40.0%)	50 (48.5%)
I frequently read the entire story as my child listens without many interruptions.	30 (28.6%)	22 (21.4%)
I frequently reread a story or book previously read to my child.	89 (84.8%)	90 (87.4%)
I frequently encourage my child to read with me, when the book uses repeated phrases or familiar rhymes.	54 (51.4%)	67 (65.0%)
None of the above are frequently a part of reading time with my child.	2 (1.9%)	1 (1.0%)

Table A24

Time Child Spends Playing Games on a Phone, Tablet, Computer, or Console Each Day (N = 105)

	Number of caregivers	Percent of caregivers
None	14	13.3%
Less than 1 hour	48	45.7%
1 to 2 hours	29	27.6%
2 to 4 hours	13	12.4%
4 to 10 hours	1	0.95%
More than 10 hours	0	0.0%
Total	105	100.0%

Table A25

Time Child Spends on Educational Apps Each Day (N = 105)

	Number of caregivers	Percent of caregivers
None	30	28.6%
Less than 1 hour	55	52.4%
1 to 2 hours	15	14.3%
2 to 4 hours	4	3.8%
4 to 10 hours	1	0.95%
More than 10 hours	0	0.0%
Total	105	100.0%

Table A26

Device Used to Access Duolingo ABC (n = 103)

Type of Device	Number of caregivers	Percent of caregivers
iPad	37	35.9%
iPhone	64	62.1%
iPad and iPhone	2	1.9%

Table A27

Owner of the Device Used to Access Duolingo ABC (n = 103)

Device Owner	Yes Frequency (%)	No Frequency (%)
The device belongs to an adult in the house, and the child borrowed the device only for this study.	65 (63.1%)	38 (36.9%)
The device belongs to an adult and the child usually uses it for games and learning apps.	35 (34.0%)	68 (66.0%)
The device belongs to the child.	7 (6.8%)	96 (93.2%)
The device is shared by multiple members of the family.	9 (8.7%)	94 (91.3%)

Table A28
Duolingo ABC Dosage and Use (N = 105)

Hours spent per week on *Duolingo ABC*	
Mean	2.08
Standard deviation	1.27
Median	1.93
Total hours spent on *Duolingo ABC* across 9 weeks	
Mean	13.15
Standard deviation	10.06
Median	12
Minutes spent during a given day on *Duolingo ABC*	
Mean	43.88
Standard deviation	18.80
Median	40.12
Days of Usage of *Duolingo ABC*	
Mean	23.41
Standard deviation	14.52
Median	20
Highest level completed on *Duolingo ABC*	
Mean	4.28
Standard deviation	2.53
Median	3.5
Percent of Learning Exercises in Which an Error was Made	
Mean	4.26%
Standard deviation	2.56
Median	4.0%
Caregivers Overrode[a] at Least One Level	
Number of caregivers (%)	63 (60.0%)

[a]Note: Caregivers were able to manually unlock, or override, a level in Duolingo ABC so that their child could complete learning exercises for the unlocked level. A caregiver might consider doing this if the child was not appropriately challenged by the current level they were on.

Table A29

Children's Interest in and Motivation for Reading, Pre-Study Survey (N = 105)

Pre-Study Survey Item	Never Freq. (%)	Occasionally Freq. (%)	Sometimes Freq. (%)	Usually Freq. (%)	Always Freq. (%)
My child asks (or demands) to be read to.	2 (1.9%)	10 (9.5%)	21 (20.0%)	35 (33.3%)	37 (35.2%)
My child wants to be read to.	0 (0.0%)	8 (7.6%)	13 (12.4%)	40 (38.1%)	43 (41.0%)
My child shows emotional reactions when I read to them.	1 (1.0%)	6 (5.7%)	20 (19.0%)	38 (36.2%)	40 (38.1%)
My child has a high level of interest in books.	2 (1.9%)	4 (3.8%)	14 (13.3%)	39 (37.1%)	46 (43.8%)

Table A30

Children's Interest in and Motivation for Reading, Post-Study Survey (n = 103)

Post-Study Survey Item	Never Freq. (%)	Occasionally Freq. (%)	Sometimes Freq. (%)	Usually Freq. (%)	Always Freq. (%)
My child asks (or demands) to be read to.	1 (1.0%)	10 (9.7%)	21 (20.4%)	41 (39.8%)	30 (29.1%)
My child wants to be read to.	1 (1.0%)	6 (5.8%)	6 (5.8%)	44 (42.7%)	46 (44.7%)
My child shows emotional reactions when I read to them.	0 (0.0%)	4 (3.9%)	16 (15.5%)	32 (31.1%)	51 (49.5%)
My child has a high level of interest in books.	1 (1.0%)	7 (6.8%)	13 (12.6%)	32 (31.1%)	50 (48.5%)

Table A31

Children's Confidence in Reading, Pre-Study Survey (N = 105)

	Never Freq. (%)	Occasionally Freq. (%)	Sometimes Freq. (%)	Usually Freq. (%)	Always Freq. (%)
My child points to some words when I read.	28 (26.7%)	35 (33.3%)	33 (31.4%)	9 (8.6%)	0 (0.0%)
My child asks me about new words/vocabulary when I read.	11 (10.5%)	22 (21.0%)	29 (27.6%)	32 (30.5%)	11 (10.5%)
My child pretends to read when looking at pictures of a book.	4 (3.8%)	8 (7.6%)	21 (20.0%)	36 (34.3%)	36 (34.3%)

Table A32

Children's Confidence in Reading, Post-Study Survey (n = 103)

	Never Freq. (%)	Occasionally Freq. (%)	Sometimes Freq. (%)	Usually Freq. (%)	Always Freq. (%)
My child points to some words when I read.	13 (12.6%)	33 (32.0%)	39 (37.9%)	14 (13.6%)	4 (3.9%)
My child asks me about new words/vocabulary when I read.	8 (7.8%)	11 (10.7%)	36 (35.0%)	36 (35.0%)	12 (11.7%)
My child pretends to read when looking at pictures of a book.	4 (3.9%)	6 (5.8%)	28 (27.2%)	28 (27.2%)	37 (35.9%)