ANNENBERG
BROWN UNIVERSITY

EdWorkingPaper No. 22-555

An Investigation of Head Start Preschool Children's Executive Function, Early Literacy, and Numeracy Learning in the Midst of the COVID-19 Pandemic

Kathleen Lynch
University of Connecticut

Monica Lee
Brown University

Susanna Loeb
Brown University

The COVID-19 pandemic's impact on preschool children's school readiness skills remains understudied. This research investigates Head Start preschool children's early numeracy, literacy, and executive function outcomes during a pandemic-affected school year, using a novel virtual assessment methodology. Study children (N = 336; mean age = 51 months; 46% Hispanic; 36% Black Non-Hispanic; 52% female) in a network of Head Start centers in four states (Nevada, New Jersey, Pennsylvania, and Wisconsin) experienced low in-person preschool exposure compared to national pre-pandemic norms. However, study children experienced fall to spring score gains during the pandemic-affected year of 0.05 SD in executive function, 0.27 SD in print knowledge, and 0.45-0.71 SD in early numeracy skills, growth not outside the general range of that observed in pre-pandemic research studies. For two of the three early numeracy domains measured, spring test score outcomes were stronger among children who attended more in-person preschool. We discuss implications for future research and policy.

VERSION: October 2022

Suggested citation: Lynch, Kathleen, Monica Lee, and Susanna Loeb. (2022). An Investigation of Head Start Preschool Children's Executive Function, Early Literacy, and Numeracy Learning in the Midst of the COVID-19 Pandemic. (EdWorkingPaper: 22-555). Retrieved from Annenberg Institute at Brown University: https://doi.org/10.26300/994d-qs85

An Investigation of Head Start Preschool Children's Executive Function, Early Literacy, and Numeracy Learning in the Midst of the COVID-19 Pandemic

Kathleen Lynch[1], Monica Lee[2], and Susanna Loeb[2]
[1]Department of Educational Psychology, Neag School of Education, University of Connecticut
[2]Annenberg Institute, Brown University
v1: 3/2022; updated 9/2022

Abstract

The COVID-19 pandemic's impact on preschool children's school readiness skills remains understudied. This research investigates Head Start preschool children's early numeracy, literacy, and executive function outcomes during a pandemic-affected school year, using a novel virtual assessment methodology. Study children (*N* = 336; mean age = 51 months; 46% Hispanic; 36% Black Non-Hispanic; 52% female) in a network of Head Start centers in four states (Nevada, New Jersey, Pennsylvania, and Wisconsin) experienced low in-person preschool exposure compared to national pre-pandemic norms. However, study children experienced fall to spring score gains during the pandemic-affected year of 0.05 SD in executive function, 0.27 SD in print knowledge, and 0.45-0.71 SD in early numeracy skills, growth not outside the general range of that observed in pre-pandemic research studies. For two of the three early numeracy domains measured, spring test score outcomes were stronger among children who attended more in-person preschool. We discuss implications for future research and policy.

Keywords: COVID-19, Head Start, preschool, executive function, early literacy, numeracy

An Investigation of Head Start Preschool Children's Executive Function, Early Literacy, and Numeracy Learning in the Midst of the COVID-19 Pandemic

The importance of young children's early experiences for their future learning and long-run educational outcomes is well-documented (e.g., Institute of Medicine and National Research Council, 2000). Beginning in 2020, the COVID-19 global pandemic precipitated abrupt and influential changes in the lives of young children. There is growing concern among researchers and policymakers that the pandemic may have harmed young children's development and acquisition of key school readiness skills (Bassok et al., 2021). Parents experienced pandemic-induced increases in stress and depression (Feinberg et al., 2022), and young children were exposed to more screen time during lockdowns (Bergmann et al., 2022), both factors that impair language development (Linebarger & Walker, 2005; Petterson & Albers, 2001). High-quality preschool supports language skills for low-income children (Dickinson & Porche, 2011; Gámez, 2015) and enriches parent-child interactions (Gelber, & Isen, 2013), but many children either experienced disruptions to their early care and education (ECE) participation during COVID-19, or they stopped attending or never began ECE at all. Even when ECE centers began reopening after initial closures, their enrollments were substantially lower than they were pre-pandemic, particularly for low-income children (Barnett & Jung, 2021; Weiland et al., 2021).

However, little research has directly assessed how preschoolers' academic skills and executive function development have fared during the pandemic. The pandemic substantially harmed older children's academic skills (West & Lake, 2021), with larger detrimental effects for Black, Latinx, and low-income children, whose communities often experienced impacts of the pandemic most directly (Domingue et al., 2021). Given the stark disruptions catalyzed by

COVID-19 to young children's home and ECE learning environments, how preschool children's development has unfolded during the crisis is important, yet it is not well understood.

The current research contributes to the evidence base by investigating the early literacy, numeracy, and executive function development of children in Head Start preschools during the COVID-19 outbreak. We examine the following questions:

1. To what extent did the early literacy, numeracy, and executive function development of children in Head Start preschools during the COVID-19 outbreak diverge from expected growth based on pre-pandemic norms?
2. How was in-person attendance at Head Start preschool centers during COVID-19 associated with early literacy, numeracy, and executive function development and parent involvement outcomes during the pandemic?

We leverage a unique dataset that includes fall and spring direct child assessments of Head Start preschoolers conducted via a novel virtual assessment methodology, as well as attendance and parent survey data. With this study, we aim both to present among the first empirical research based on direct child assessments on this topic, and to urge new research in this arena.

The current research makes three key contributions. First, the setting is important and understudied. Head Start programs have provided federally-funded free child care to over 37 million low-income children in the United States to date, and the United States spends over $10 billion annually on Head Start and Early Head Start (National Head Start Association, 2022). Research on how COVID-19 influenced Head Start participants is quite limited, despite the fact that Head Start enrollees are a critical population of predominantly Black, Latinx, and low-income children whose communities faced disproportionate pandemic impacts. Second, most prior studies of the impact of COVID-19 in ECE settings have relied on teacher and parent surveys, which are subject to self-report bias. Very few studies have administered remote direct assessments of preschoolers during COVID-19 (for an exception, in executive function, see Ahmed et al., 2022) and to our knowledge few or none have data from more than one point in time that would allow an examination of growth. We use direct child assessments conducted in both fall and spring, as described below. Third, while some informative research has explored preschool absenteeism in a non-pandemic school year (Ansari & Purtell, 2018), the volume of in-person preschool that children have missed during the pandemic dwarfs the levels examined in prior research. Thus, new research specifically using attendance data and addressing the pandemic period is needed to examine how children's development progressed under a regimen of substantially reduced access to preschool.

The Importance of Early Academic Skills, Executive Function, and Parent Involvement for Preschoolers

Early print knowledge and numeracy are important skills for both kindergarten readiness and later educational attainment (e.g., Clements et al., 2013; Longian et al., 2000; Moffitt et al., 2011). Print knowledge is comprised of pre-reading concepts including knowledge of letters, words, and conventions of books and printed materials (Sawyer et al., 2014; Storch & Whitehurst, 2002), and early print knowledge predicts children's subsequent reading achievement (Language and Reading Research Consortium & Chiu, 2018; Piasta et al., 2012). Preschoolers' early numeracy skills are associated with their mathematics achievement in the later grades (Watts et al., 2014). Executive functioning supports academic performance as well as future behavioral and social outcomes (e.g., Blair & Razza, 2007; Evans & Rosenbaum, 2008; Moffitt et al., 2011).

Parent involvement is also a supportive factor for preschoolers' learning. Parent involvement may be conceptualized in myriad ways, including via the classifications of school-based involvement, school communication, and home-based involvement (Fantuzzo et al., 2000; see also, e.g., Comer & Haynes, 1991, Sénéchal & Young, 2008; and for a broader conceptualization of the construct, see e.g., Dimmock et al., 1996), which are overlapping. School communication may involve parents' and teachers' discussion of topics including the child's academic and social development, as well as the family context; such communications are recommended in policy reports (e.g., Department of Education, Employment and Workforce Relations, 2009; National Association for the Education of Young Children, 2011). School-based involvement, such as parents' attendance at school activities or school volunteering, is linked to better child academic performance and affective factors such as academic motivation (Parker et al., 1997; Stevenson & Baker, 1987). Home-based involvement is comprised of parent-child educational interactions and other means that parents use to support children's cognitive development outside of school time (Fantuzzo et al., 2000). For example, parent-child book-reading and parents' mathematical talk predict future literacy and mathematics achievement, respectively (Levine et al., 2010; Sénéchal & Young, 2008), and open-ended parent-child conversations about topics such as books and the world around children can bolster language and mathematics skills (McCormick et al., 2020; Paris, 2005).

Some research suggests that intervention-induced gains in early literacy and mathematics may fade out in early elementary school (e.g., Burchinal et al., 2022); however, other evidence indicates that high-quality early childhood programming can improve children's long-run outcomes even in cases where an early skills advantage appears to fade out (Yoshikawa et al., 2013). This conclusion is reflected in influential policy documents that highlight recommendations for building mathematics and literacy competencies in the preschool years (e.g., National Mathematics Advisory Panel, 2008; U.S. Department of Health and Human Services, 2015), and research findings that preschool mathematics is an important foundation for later performance (Duncan et al., 2007).

Low-Income Preschoolers' Development During the COVID-19 Pandemic

Since the start of the COVID-19 pandemic, children's schooling has suffered large-scale upheaval. In many areas of the United States, including major metropolitan areas such as Boston, Los Angeles, and Washington, D.C., public elementary, middle, and high schools maintained online learning and school buildings were closed to the majority of children for most of a full year (Institute of Education Sciences, 2021). A growing body of evidence documents that pandemic-induced schooling stoppages have caused older students to fall behind academic benchmarks (West & Lake, 2021) and worsened their social-emotional well-being (Hamilton & Gross, 2021), particularly among low-income students and students from racially minoritized backgrounds (Amplify, 2021; Domingue et al., 2021).

Despite growing evidence of the pandemic's effects on K-12 students, the impact of the pandemic on preschool-aged children's development remains understudied. We note that it is not obvious to what extent we would expect preschool-aged children to experience learning and developmental setbacks during the pandemic. On the one hand, there are several reasons to predict development risks for young children during COVID-19, particularly in low-income contexts. Prior research indicates that Head Start increases parent-child involvement (Gelber & Isen, 2013) and, despite fadeout of achievement impacts (U.S. Department of Health and Human Services, 2010), benefits children's long-run outcomes (Deming, 2009; Ludwig & Miller, 2007). Preschool absences during a non-pandemic year have been linked to poorer achievement (Ansari

& Purtell, 2018); thus the much lower-than-typical exposure to Head Start during the pandemic may have been expected to predict weaker academic skills and parent involvement. Teachers reported that preschoolers struggled under virtual learning, due to inadequate instructional offerings, parents' difficulties supervising online preschool while they worked, preschoolers' need for physical activity and difficulty sitting in front of computers, and the difficulty preschoolers have learning social and school readiness skills when not in-person (Bassok et al., 2021). Parents also reported worsened home behaviors during remote learning (Hanno et al., 2022). Given that older students, who struggled with similar issues, experienced substantial achievement setbacks, we might expect analogous learning lags among preschoolers, or even larger ones, if virtual learning was especially ill-suited to preschoolers developmentally. From a theoretical standpoint, we may expect Head Start preschoolers' learning trajectories to be significantly harmed by COVID-19 because low-income communities are predicted to bear disproportionate burdens from a pandemic (Baez et al., 2010), as initial disadvantages are exacerbated (Ceci & Papierno, 2005). Moreover, the amalgamation of the pandemic with existing racial inequities may disproportionately harm children from communities of color (e.g., Solomos, 2021). Simultaneously, as Ansari and Purtell (2018) argued, because the compensatory hypothesis implies the prediction that universal preschool programs will reduce social inequality (Barnett, 1992; Raudenbush & Eschmann, 2015), we may expect Head Start access to mitigate harms to low-income children's development.

On the other hand, it is conceivable that the various influences could have ameliorated learning risks to preschoolers during the pandemic, such as local regulations that allowed ECE centers to remain open more frequently than public schools, and/or intensive compensatory efforts by parents and ECE teachers to bolster preschoolers' learning while they were at home. If

Head Start children whose parents had more resources to substitute for the loss of preschool stayed home more frequently, relationships between in-person Head Start exposure and child outcomes may be attenuated. It is also possible that the treatment-control contrast of in-person schooling versus staying home during the pandemic may have been smaller for Head Start preschoolers than has been observed for older students in national studies, for example if selection effects operated differently in the Head Start sample such that the parents whose children spent more time at home were especially well-equipped to provide substitute learning opportunities. Thus it remains unclear but important to know how preschoolers' learning and development have fared during the pandemic's progression.

Method

Participants

Study participants were a sample of children ($N = 336$) enrolled in a network of Head Start centers located across four states (Nevada, New Jersey, Pennsylvania, and Wisconsin) during the 2020-21 school year. As we described previously in Groom-Thomas et al. (2022), data collection proceeded as follows. We originally set the goal of assessing up to 30% (or 600) of all Head Start children across the four study locations. Program staff at the organization that operates the centers used the random function in Excel to randomly select 600 students. Of these, assessments were ultimately collected for 336 children who comprise the current sample. The number of children assessed was lower than that recruited for several reasons. Scheduling difficulties for virtual assessment appointments during this phase of the pandemic were substantial, as centers and classrooms frequently closed due to COVID-19 outbreaks and local public health ordinances, and children were frequently absent due to COVID illnesses and exposure-induced quarantines. In addition, as is frequently the case in research studies, a number of parents/caregivers declined participation in assessments both initially and throughout the year, while other children withdrew from the Head Start centers and were not subsequently assessed. We could not and did not track specific reasons for parents/caregivers' nonparticipation during pandemic data collection.

Table 1 presents descriptive information for the study sample; comparisons between the full enrollee population at the participating Head Start centers, the students randomly selected for assessments, and the final assessment sample; as well as comparisons to nationally representative Head Start samples. Participating children were identified by their caregivers predominantly as Black (36%) or Hispanic (46%). Mean age was 50.82 months. Most children's (91%) highest level of parent education was less than a bachelor's degree; and 35% had a home language besides English (see Table 1 for other sample statistics). Compared with a nationally representative Head Start sample, study participants were similarly likely to be Black non-Hispanic, more likely to be Hispanic, less likely to be White or Asian non-Hispanic, and more likely to have a home language besides English. Study children's fall executive function scores were 0.10 SD higher than the national mean (see Table S1 for descriptive statistics for all child assessments and parent survey measures). Study children were also somewhat more likely to be age 4 than age 3 as compared to the national pre-pandemic sample; Table 1 suggests this was likely driven in part by random sampling variability, although it also may have been the case that parents of 4-year-olds (who were often program returners from the prior year) were more likely to enroll their children in Head Start than parents of 3-year-olds during the pandemic. As we describe below, all child assessment scores are scaled to be age-adjusted, such that each child's gain scores may be compared to typical growth of a same-age norming sample; thus comparisons of conclusions about preschoolers' score growth across studies are not expected to be substantially affected by small variations in the age compositions of the studies' samples.

Measures

Child Outcomes

We assessed *print concepts* understanding as an indicator of early literacy using the Print Knowledge subtest of the Test of Preschool Early Literacy (TOPEL; Lonigan et al., 2007), which captures alphabet knowledge and knowledge of written language conventions and forms. The Print Knowledge subtest comprises 36 multiple-choice items. Assessors shared with children a digital version of the test flipbook using Zoom's screen share feature. Assessors read each prompt aloud, asking children to select the best response (e.g., "Which is the letter /k/?"). Scores were converted to standard scores that permit same-age peer comparisons. Internal consistency reliability (Cronbach's alpha) for the analytic sample for the spring assessment was 0.95.

Early numeracy was measured using three subtests of the Individual Growth and Development Indicators of Early Numeracy (IGDI-ENs; Hojnoski & Floyd, 2012). The *Oral Counting* subtest indexes the child's ability to count fluently. Children are asked to count aloud in sequence beginning at one; the score is the highest number the child reaches in one minute before making an error. *Number Naming* measures the ability to identify numerals. Children are asked to identify the numerals 1 to 20, presented in random order; the score is the number correctly identified. *Quantity Comparison* indexes the ability to judge differences in the quantity of object groups. Children are shown a series of images which each display two dice faces showing 1-6 dots and asked to identify the die 'with more.' The child's score equals the number of images identified correctly within one minute. As above, digital flipbooks and the Zoom screen share feature were used to conduct the assessments. Raw scores are used in analyses. Cronbach's alpha for the analytic sample for the spring Quantity Comparison subtest was 0.90;

traditional sample internal consistency reliability statistics were not estimable for the Oral Counting and Number Naming subtests due to the way scores for these assessments are constructed; however, publisher-reported test-retest reliabilities for these measures ranged from 0.71-0.88. Prior research comparing remote and in-person administration of IGDI assessments showed that the two assessment modalities yielded similar scores (Greenwood et al., 2021); however note that the research was conducted with infants and toddlers using different subtests.

We assessed *executive function*, including working memory, inhibitory control, and cognitive flexibility, using the Minnesota Executive Function Scale (MEFS; Carlson & Zelazo, 2017). MEFS has been used in prior federally-funded Head Start research (Kopack Klein et al., 2021). MEFS is an adaptive assessment administered via a tablet app (publisher-reported test-retest reliability = 0.93; as above, sample internal consistency reliabilities were not estimable given the nature of the reported scores). Assessors read prompts aloud to children, and asked children to select one of two options that best matched the prompt (for example, "We are going to play the color game. This is a blue box and this is a green box. All green bicycles go in the green box, all blue bicycles go in the blue box. Where does this one go?"). Scores were derived from the publishers' guidelines for age-adjusted scores that permit same-age peer comparisons.

Parent Surveys

To measure *parent-child educational interactions,* parents reported how many times they had done each of a set of activities with their child in the last week. We operationalized *parent-school trust and involvement* using four survey items. For both indices, we summed and standardized parents' responses to create an overall index score for analyses (see Table S2 for items). We measured *teacher communication frequency* using a dichotomous indicator of whether the parent reported communicating with their child's teacher once or more in an average week.

Exposure to In-Person Preschool

Attendance and child demographic data were collected from administrative files. We operationalized children's exposure to in-person Head Start preschool as number of days attended per calendar month, calculated by dividing the total number of days the student was present in-person by their total months enrolled in the program.

Beyond routine absences, children were absent in the focal school year for several pandemic-specific reasons. First, children missed in-person days due to parents' preferences for virtual learning. Children whose parents opted for virtual learning at the beginning of the fall semester were enrolled in virtual Head Start programming. The virtual programming, which was the same across the four states, comprised weekly one-on-one teacher-child Zoom meetings, and encouragement to access a website with educational links. Parents could change their programming preference (virtual versus in-person) whenever they chose, and many parents did so. In centers where more parents expressed interest in in-person enrollment than there were spaces available, children were placed on a waitlist. Waitlisted children began the year in virtual learning, and were offered an in-person spot as soon as one became available. Second, classrooms closed intermittently due to virus outbreaks and public health ordinances. Third, children were excluded from school when they were being quarantined. Head Start records do not permit us to parse the relationships between various reasons for child absences and student outcomes separately; this notwithstanding, we view absences for all reasons as contributors to the construct of interest: Children's ultimate level of exposure to in-person preschool during the pandemic-affected school year 2020-21. In a sensitivity check, analyses using raw days of in-person attendance yielded the same pattern of findings as those below.

Procedures

Virtual Assessments

Child-level literacy, numeracy, and executive function assessments in fall and spring were conducted one-on-one via a virtual assessment model (see Groom-Thomas [2022] for a detailed discussion). At the beginning of the school year, Head Start centers provided tablets and Internet hotspots to all families that needed them. The assessments we used are traditionally administered in-person. Due to public health restrictions in place during data collection, we used a virtual model for all assessments. All participating children, including both those attending Head Start in-person and those attending virtually (i.e., at home), were administered the assessments remotely. Children attending preschool in-person at assessment time completed the assessments using Internet-connected devices in their classrooms. Those enrolled in the virtual model at the time of the assessment completed the assessments via Internet-equipped devices at home. Trained assessors, all of whom were remote while conducting the assessments, used the screen share feature in Zoom to show children publisher-provided digital versions of the test materials.

Parent Surveys

Head Start centers administered parent surveys in the spring via email and text message, using means consistent with the centers' regular family communications (response rate: 77%).

Analytic Approach

We begin by presenting descriptive information on children's in-person Head Start attendance during the pandemic-affected school year. We present bivariate correlations between each of the child outcome measures between fall and spring and, following e.g., Ahmed et al. (2022), within wave as an indicator of concurrent validity, with the hypothesis that we would observe small to moderate positive correlations between indicators.

To examine the relationship between preschool exposure and learning outcomes, we fit a series of regression models predicting children's spring outcomes in early print knowledge, numeracy, and executive function, respectively, as a function of their in-person attendance, controlling for fall scores and demographic indicators. Our primary models were fit with center fixed effects and robust standard errors, and controlled for child demographics including race, gender, age, English as a home language, parent education, single parent household, and assessment location (home versus school).

Next, we fit a second series of regression models predicting parent-child interactions, parent-school trust and involvement, and parent-teacher communication, respectively, as a function of their in-person attendance, with center fixed effects and robust standard errors, and controlling for baseline executive function and the same vector of demographic controls as above (controlling for other fall skills yields the same pattern of results).

We conducted a series of sensitivity checks to examine the robustness of the findings to missing data and modeling variations. First, we refit all models using multiple imputation to account for missing data (Royston & White, 2011). Second, we fit models including a dichotomous indicator indexing children who attended no in-person days, to examine potential differences for never-attenders on the measured outcomes, controlling for baseline scores and the other demographic indicators noted previously. Lastly, we refit the above models using negative binomial regression, a common approach for over-dispersed count data (Hilbe, 2011) such as in the case of pandemic attendance. It is important to note that student attendance is endogenous in most research studies and contexts (e.g., Liu et al., 2021) and as we described above, the pandemic was no exception. We could not and did not document the reasons for different absences. Thus the data we have do not permit us to draw causal conclusions about the effects of pandemic preschool attendance. Rather, our aim is to illuminate growth patterns and predictors of child academic and executive function outcomes within a descriptive framework.

To contextualize learning growth, for print knowledge and executive function, we compare study children's growth to expected growth for children's age based on test developers' norming samples. Specifically, we computed the difference between fall and spring scores divided by each assessment's normed standard deviation. For TOPEL print knowledge, the Head Start network involved in the current study assessed children on the same measure during the most recent pre-pandemic school year (2018-2019), allowing us to compare growth for our sample to this prior year sample. For IGDIs, assessment norming data did not exist; thus we used the standard deviation of each fall subtest score to compute standardized fall-spring gains.

Results

In-Person Preschool Attendance

Head Start preschoolers in the current sample who began the year in virtual learning attended an average of 6.31 days per month of in-person Head Start, while those who began the year enrolled in the in-person model attended an average of 12.66 days per month. Among study children who attended in-person for at least one day during the school year, mean days of in-person preschool was 11.93 days per month. Figure 1 plots the distribution of monthly in-person attendance for each of those groups.

Did Head Start Preschoolers Experience Gains in School Readiness Skills During the Pandemic-Affected School Year?

Table 2 shows bivariate correlations among the child outcomes used in the study. Fall and spring scores were significantly and moderately to strongly correlated at the $p < 0.01$ level for all indicators but the IGDI-QC subtest (*r*s: TOPEL: 0.73; IGDI-NN: 0.68; IGDI-OC: 0.34; IGDI-QC: 0.09; MEFS: 0.28). Print knowledge assessment scores from fall and spring were moderately and significantly correlated with concurrent oral counting, number naming, and executive function assessments (*r*s = 0.28 - 0.63; $p < 0.01$); quantity comparison was significantly correlated with print knowledge in spring only ($r = 0.46$; $p < 0.01$). Executive function assessments were significantly correlated with both fall and spring oral counting (*r*s = 0.15 - 0.29, $p <= 0.01$) and with fall number naming ($r = 0.20$, $p < 0.01$); the correlation between spring executive function and quantity comparison was marginally significant ($r = 0.11$, $p < 0.10$). The subtest that showed the weakest correlations with other outcomes was fall quantity comparison; spring quantity comparison was moderately and significantly correlated with print knowledge and marginally significantly correlated with executive function. We note that fall subtests are controls in our models, and models control for baseline scores in all domains. The other correlations are generally in the same range as those found between remotely-assessed executive function and literacy assessments in Ahmed et al.'s (2022) validation study of remote executive function tasks with preschoolers, strengthening confidence that the scores derived from the remote assessments captured useful information.

Descriptively, study children experienced mean gains in school readiness skills during the pandemic-affected school year (Table 3). In *print knowledge*, study children achieved fall to spring gains that were 0.27 SD greater than expected for their age, with mean scores increasing from the 40th percentile of the test norming sample in the fall to the 50th percentile at spring posttest (using a calculation for the translation of effect sizes to percentile ranks presented in

Lipsey et al., 2012; Lonigan et al., 2007). In *early numeracy*, study children gained an average of 0.71 SD in oral counting, 0.45 SD in number naming, and 0.71 SD in quantity comparison. In *executive function*, study children experienced growth that was 0.05 SD higher than expected for their age, with average scores increasing from the 44rd percentile of the assessment norming sample in the fall to the 46th percentile in the spring (Carlson & Zelazo, 2017).

Associations Between In-Person Preschool Exposure and Child Outcomes During the Pandemic-Affected Year

Table 4 (top panel) provides the results of multivariate analyses predicting spring child outcomes as a function of in-person attendance, controlling for prior scores and background characteristics as well as center fixed effects. On average, children who attended more in-person preschool during the pandemic year had significantly better learning outcomes in print knowledge ($b = 0.47$; $p < 0.05$) and number naming ($b = 0.83$; $p < 0.01$) than those who attended fewer days of preschool in-person. Children who attended more days of in-person Head Start also had higher mean oral counting scores than children who attended fewer in-person days; this difference was marginally significant ($b = 0.459$; $p < 0.10$). Spring outcomes in executive function and quantity comparison were not significantly associated with exposure to in-person preschool in the multivariate models.

Table 4 (bottom panel) shows the results of multivariate models predicting family outcomes as a function of children's in-person attendance during the pandemic-affected year. The coefficients are small in magnitude and none of the associations examined were statistically significant.

We conducted a series of sensitivity checks to examine the sensitivity of the primary findings to model variations and missing data. Table S3 shows that refitting the primary models using multiple imputation to account for missing data yields results similar to those above. Table S4 shows the results of adding to the main models a dummy indicator indexing children who did not attend any days of in-person programming, to examine the extent to which these children differed on the measured outcomes from their counterparts, controlling for baseline scores and the other indicators. The coefficient on this indicator is statistically significant only for the oral counting variable. When this indicator is added to the models, the associations between oral counting and number naming with in-person attendance remain statistically significant; the coefficient for print knowledge remains positive in sign but is no longer statistically significant. Models refit with negative binomial regression and site fixed effects did not achieve convergence; the pattern of findings from models refit using negative binomial regression trimmed of site fixed effects is similar to that observed in the model including the indicator for non-attenders (see Table S5). Although these differences may be stochastic given the data limitations inherent in the relatively small sample, they are consistent with a conclusion that the association between attendance and print knowledge may have been driven by weaker print knowledge outcomes among children who never attended in-person, while associations between in-person attendance with oral counting and number naming were robust to the inclusion of children with no in-person attendance days. Finally, we fit interaction models to explore whether relationships between in-person attendance and outcomes differed significantly by baseline skills; none of the interactions examined were statistically significant (not shown).

Discussion

Overall, study children in Head Start experienced a fraction of the in-person preschool that would have been expected in a pre-pandemic year based on prior research. This was true even among children who began the year in in-person learning. Ansari and Purtell (2018) found that Head Start children in a nationally representative sample in 2009-10 were absent for an average of 5.48% of the school year, or the equivalent of attending roughly 170 days in a hypothetical 180-day school year. Extrapolating this calculation to the current sample, children in the present study who began the year in in-person learning would have attended the equivalent of roughly 111 in-person preschool days in a hypothetical 180-day school year, while those who began the year in virtual learning would have attended approximately 55 days.

Despite relatively low levels of in-person preschool attendance, children experienced mean gains in school readiness skills over the course of the year. Although data did not exist to compare growth during the pandemic to prior growth for the study children, examples from pre-pandemic research studies are broadly suggestive of potential noteworthy comparisons.

To draw comparisons, we used findings from recent studies assessing preschoolers in Head Start or other predominantly low-income settings (Figure 2). Although comparisons are not precise, the pattern of findings is consistent with the conclusion that study children's gains were not outside the general range of those observed in pre-pandemic research studies. In print knowledge, during pre-pandemic (2018-19) children enrolled in the same network of Head Start centers as the study children achieved fall-spring TOPEL gains 0.24 SD greater than expected for their age, similar to study children's gains of 0.27 SD. In numeracy, the IGDI developers found that Head Start preschoolers experienced fall to spring gains of 0.48 SD (oral counting), 0.44 SD (number naming), and 0.78 SD (quantity comparison), respectively (Hojnoski et al., 2009). Study children experienced mean numeracy gains in the same general span (approximately 0.45-0.71 SD across subtests). In another pre-pandemic study of a nationally representative sample of Head Start preschoolers, albeit using a different assessment, researchers found average gains of 0.53 SD in early numeracy (Ansari & Purtell, 2018). In executive function, a recent pre-pandemic longitudinal study that examined preschoolers' fall to spring MEFS executive function gains in a primarily low-income sample found average gains of 0.06 SD (Anderson et al., 2020), in the same range as those observed in the current study (0.05 SD).

Overall, we found that although not for executive function and not consistently across models for print knowledge, for two of the three early numeracy domains measured, outcomes were stronger among children who attended more in-person preschool. The observation that study children experienced school readiness gains during the pandemic-affected school year leads to questions about the mechanisms that supported this growth. On the one hand, this finding may seem surprising, given that research conducted with older students has documented large pandemic-induced learning setbacks (e.g., U.S. Department of Education, 2022). However, child care centers tend to operate under different regulations than public school districts, and in many localities ECE centers were able to reopen in-person during periods when public school buildings remained closed (Kim et al., 2022). As a result, children enrolled in preschool may have missed less school on average than older students, contributing to fewer learning setbacks. Another possibility is that parents may have found it easier to 'home teach' preschool concepts, such as oral counting, as compared with the more advanced mathematics and other academic content that older students were expected to learn, and as such parents may have been better able to buffer to effects of school closures on preschoolers' than older students' learning outcomes.

Increased household stress during the pandemic and reduced exposure to Head Start may also have been expected to worsen preschoolers' outcomes and lower measures of parent involvement. Prior research suggests that family disorganization and chaos predict lower executive function growth in young children (Hughes & Ensor, 2009); since the pandemic likely caused increased home disorganization, we might have predicted children who spent more time at home (versus school) during the pandemic to have worse executive function outcomes. Similarly, Head Start has been found to increase parent involvement (Gelber & Isen, 2013); thus we might have expected lower in-person Head Start exposure during the pandemic to predict lower parent involvement outcomes. However, we did not observe statistically significant associations between executive function outcomes nor parent outcomes in our data.

One possible explanation for this pattern of findings may be that during the pandemic-affected year, an amalgamation of selection effects and exceptional efforts by parents and ECE centers yielded the combined result of buffering the impacts of the pandemic on young children's school readiness skills. Head Start parents that were better-positioned to compensate for preschool closures with home learning supports may have opted to keep their children home more frequently during the COVID-19 outbreak. Speculatively, perhaps parents concentrated these efforts more on early literacy and executive function skills than numeracy, a domain parents often consider the purview of school (e.g., Cooper et al., 1996). In this scenario, the lack of a consistent association between pandemic preschool absences and child outcomes may be explained by the fact that in descriptive research, researchers observe relationships in equilibrium. For example, if parents whose children are assigned to teachers whose instruction is weak disproportionately enroll their children in tutoring programs to compensate, observed correlations between child test scores and teachers' instructional quality will be attenuated (Hill et al., 2011). Head Start parents and caregivers whose children were home more frequently may have responded to reduced preschool access by intensifying their own efforts to teach their children early skills, thus mitigating the immediate effects of preschool absences on their children's development. Teachers and ECE staff also provided supports that may have mitigated the effects of absences, including parent outreach, links to web-based learning materials, and, for children enrolled in virtual programming, weekly Zoom videoconference meetings.

At the same time, perhaps children attending in-person may have benefitted from unexpected affordances, such as smaller class sizes than they would have experienced during a non-pandemic year. Like many Head Start centers and other ECE programs (e.g., statewide in California; Kim et al., 2022), anecdotally, the partner organization reported that centers reduced class sizes to accommodate social distancing. Smaller class sizes in Head Start predict lower teacher job stress (Friedman-Krauss et al., 2014), stronger child literacy outcomes, and increased teacher-child interaction time (Francis & Barnett, 2019), a hypothesized support for executive function development (Neitzel & Stright, 2003). Future research comparing measures of classroom instructional quality before and during COVID-19 would be helpful to shed light on how preschoolers' classroom experiences were affected by the pandemic, including potential classroom-level supportive factors that may have strengthened pandemic learning outcomes.

However, even if the above hypotheses prove correct, parents' taking of unusual steps to support preschoolers during the pandemic almost certainly would have had costs to families not visible in these data, and such efforts would likely be unsustainable in the long term. Many parents, particularly mothers, reduced work hours or delayed seeking new employment after a layoff in order to care for children at home during the pandemic (Alon et al., 2020). Reallocating parents' time comes with costs (Robinson et al., 2022). Such shifts may have bolstered preschoolers' learning, but with negative side effects such as lower household financial stability and parental stress from 'homeschooling.' Extra work undertaken by teachers may also have buttressed children's learning, but with a cost of increased staff burnout risk (Hanno et al., 2022).

The current findings point towards several promising avenues for future research. First, more research is warranted to understand how low-income preschoolers' parents responded to the pandemic, including qualitative interview and survey studies of parents whose children attended more and fewer days of in-person Head Start, as well as parents who declined to send their children to Head Start altogether. Such research could shed light on how families altered their household dynamics to accommodate Head Start absences during the pandemic; sources of strength that families drew on to support children's learning amidst child care disruptions; and potential side effects of these shifts on children that may implicate needs for future supports.

Second, this study contributes to a small yet growing evidence base pointing toward the promise of a novel methodology, virtual direct child assessments with preschoolers. We used digital assessment materials to directly assess hundreds of Head Start preschoolers via videoconference. Other researchers can build on this work, and adapt the methods to new contexts, potentially reducing research costs for in-person assessments. The correlations we observed among the study assessments were similar to those found other recent research validating remote assessments with preschoolers (Ahmed et al., 2022). Future comparative studies of in-person versus virtual assessment conditions, benefits, and costs is warranted; this notwithstanding, even if virtual assessments do not ultimately have the same psychometric properties as in-person tests, they were an essential aid during the pandemic, and they may well be needed in future situations where schooling is disrupted. Given the importance of early screening for identifying young children at risk for developmental delays, we argue that child assessments even during times of schooling upheaval remains vital.

Second, our measures captured important aspects of academic achievement and executive functioning, yet more research is needed to capture other domains of child well-being. From an ecological perspective (Bronfenbrenner, 1979), preschool closures and virtual preschool affect the ecology of the family, including parents' ability to work and family stress. These factors may have been expected to influence other dimensions of children's skills beyond those we measured, including social and behavioral adjustment (e.g., Mistry et al., 2004), and more studies are needed to address those dimensions. Additionally, as the current study sample was relatively small, additional studies with larger and nationally representative samples, along with studies following preschoolers' progress post-pandemic, are warranted.

Our findings confirm prior reports showing lower preschool attendance during the pandemic. In response, early childhood centers may need to increase their parent outreach to rebuild preschool attendance. Strategies such as fostering parent relationships, communicating attendance goals, and engaging community partners show promise (Kalil et al., 2021; Katz et al., 2016; Sommer et al., 2020). Moreover, offering children more instructional time, such as via tutoring (Nickow et al., 2020) and summer programs (Kim & Quinn, 2013; Lynch et al., 2022), is a research-based avenue to support children's progress. The observation that children with lower in-person preschool exposure had worse numeracy outcomes, on average, suggests that these children may particularly benefit from support for missed numeracy learning opportunities.

In summary, this study aims to provide new evidence and spur future research on preschoolers' experiences during COVID-19, particularly using direct child assessments. Producing this knowledge is a critical step in determining the impacts of the pandemic on young children's development, as well as identifying needed resources to support children's pandemic-related recovery and educational opportunities in the future.

References

Ahmed, S. F., Skibbe, L. E., McRoy, K., & Tatar, B. H. (2022). Strategies, recommendations, and validation of remote executive function tasks for use with young children. *Early Childhood Research Quarterly*, *60*, 336-347.

Alon, T., Doepke, M., Olmstead-Rumsey, J., & Tertilt, M. (2020). *The impact of COVID-19 on gender equality* (No. w26947). National Bureau of Economic Research.

Amplify. (2021). *COVID-19 means more students not learning to read*.

Anderson, K. L., Weimer, M., & Fuhs, M. W. (2020). Teacher fidelity to Conscious Discipline and children's executive function skills. *Early Childhood Research Quarterly*, *51*, 14-25.

Ansari, A., & Purtell, K. M. (2018). Absenteeism in Head Start and children's academic learning. *Child Development*, *89*(4), 1088-1098.

Baez, J., De la Fuente, A., & Santos, I. V. (2010). Do natural disasters affect human capital? An assessment based on existing empirical evidence. IZA Discussion Paper No. 5164

Barnett, W. S. (1992). Benefits of compensatory preschool education. *Journal of Human Resources*, 279-312.

Barnett, W. S., & Jung, K. (2021). Seven impacts of the pandemic on young children and their parents: Initial findings from NIEER's December 2020 preschool learning activities survey. National Institute for Early Education Research.

Bassok, D., Weisner, K., Markowitz, A. J., & Hall, T. (2021). *Teaching young children during COVID-19: Lessons from early educators in Virginia*. University of Virginia.

Bergmann, C., Dimitrova, N., Alaslani, K., Almohammadi, A., Alroqi, H., Aussems, S., ... & Mani, N. (2022). Young children's screen time during the first COVID-19 lockdown in 12 countries. *Scientific Reports*, *12*(1), 1-15.

Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development*, *78*(2), 647-663.

Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design*. Cambridge, MA: Harvard University Press.

Burchinal, M., Foster, T., Garber, K., Cohen-Vogel, L., Bratsch-Hines, M., & Peisner-Feinberg, E. (2022). Examining three hypotheses for pre-kindergarten fade-out. *Developmental Psychology*.

Carlson, S. M., & Zelazo, P. D. (2017). Minnesota Executive Function Scale: Technical Report. St. Paul, MN: Reflection Sciences.

Ceci, S. J., & Papierno, P. B. (2005). The rhetoric and reality of gap closing: when the" have-nots" gain but the" haves" gain even more. *American Psychologist*, *60*(2), 149.

Clements, D. H., Sarama, J., Wolfe, C. B., & Spitler, M. E. (2013). Longitudinal evaluation of a scale-up model for teaching mathematics with trajectories and technologies: Persistence of effects in the third year. *American Educational Research Journal*, *50*(4), 812-850.

Comer, J. P., & Haynes, N. M. (1991). Parent involvement in schools: An ecological approach. *The Elementary School Journal*, *91*(3), 271-277.

Cooper, H., Nye, B., Charlton, K., Lindsay, J., & Greathouse, S. (1996). The effects of summer vacation on achievement test scores: A narrative and meta-analytic review. *Review of Educational Research*, *66*(3), 227-268.

Deming, D. (2009). Early childhood intervention and life-cycle skill development: Evidence from Head Start. *American Economic Journal: Applied Economics*, *1*(3), 111-34.

Department of Education, Employment and Workforce Relations. (2009). Belonging, being and becoming: The early years learning framework for Australia. Canberra: Commonwealth of Australia.

Dickinson, D. K., & Porche, M. V. (2011). Relation between language experiences in preschool classrooms and children's kindergarten and fourth-grade language and reading abilities. *Child Development*, *82*(3), 870-886.

Dimmock, C. A., O'Donoghue, T. A., & Robb, A. S. (1996). Parental involvement in schooling: An emerging research agenda. *Compare*, *26*(1), 5-20.

Domingue, B. W., Hough, H. J., Lang, D., & Yeatman, J. (2021). *Changing patterns of growth in oral reading fluency during the COVID-19 pandemic*. Policy Analysis for California Education (PACE).

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., & Japel, C. (2007). School readiness and later achievement. *Developmental Psychology*, 43, 1428–1446. doi:10.1037/0012-1649.43.6.1428

Evans, G. W., & Rosenbaum, J. (2008). Self-regulation and the income-achievement gap. *Early Childhood Research Quarterly*, *23*(4), 504-514.

Fantuzzo, J., Tighe, E., & Childs, S. (2000). Family Involvement Questionnaire: A multivariate assessment of family participation in early childhood education. *Journal of Educational Psychology*, *92*, 367–376.

Feinberg, M. E., Mogle, J., Lee, J. K., Tornello, S. L., Hostetler, M. L., Cifelli, J. A., ... & Hotez, E. (2022). Impact of the COVID-19 pandemic on parent, child, and family functioning. *Family Process*, *61*(1), 361-374.

Francis, J., & Barnett, W. S. (2019). Relating preschool class size to classroom quality and student achievement. *Early Childhood Research Quarterly*, *49*, 49-58.

Friedman-Krauss, A. H., Raver, C. C., Neuspiel, J. M., & Kinsel, J. (2014). Child behavior problems, teacher executive functions, and teacher stress in Head Start classrooms. *Early Education and Development*, *25*(5), 681-702.

Gámez, P. B. (2015). Classroom-based English exposure and English language learners’ expressive language skills. *Early Childhood Research Quarterly*, *31*, 135-146.

Gelber, A., & Isen, A. (2013). Children's schooling and parents' behavior: Evidence from the Head Start Impact Study. *Journal of Public Economics*, *101*, 25-38.

Hamilton, L., & Gross, B. (2021). How has the pandemic affected students' social-emotional well-being?: A Review of the evidence to date. *Center on Reinventing Public Education*.

Hanno, E. C., Gardner, M., Jones, S. M., & Lesaux, N. K. (2022). An ecological perspective on early educator well-being at the start of the COVID-19 pandemic. *Early Childhood Research Quarterly*, *60*, 214-225.

Hilbe, J. M. (2011). *Negative binomial regression*. Cambridge University Press.

Hill, H. C., Kapitula, L., & Umland, K. (2011). A validity argument approach to evaluating teacher value-added scores. *American Educational Research Journal*, *48*(3), 794-831.

Hojnoski, R., & Floyd, R. G. (2012). Individual growth and development indicators – Early Numeracy. Bloomington MN: Early Learning Labs/Renaissance Learning.

Hojnoski, R. L., Silberglitt, B., & Floyd, R. G. (2009). Sensitivity to growth over time of the preschool numeracy indicators with a sample of preschoolers in Head Start. *School Psychology Review*, *38*(3), 402-418.

Hughes, C. H., & Ensor, R. A. (2009). How do families help or hinder the emergence of early executive function?. *New directions for child and adolescent development*, *2009*(123), 35-50.

Institute of Education Sciences. (2021). Monthly School Survey Dashboard.

Institute of Medicine and National Research Council. (2000). From neurons to neighborhoods: The science of early childhood development. Washington, DC: National Academies Press.

Kalil, A., Mayer, S. E., & Gallegos, S. (2021). Using behavioral insights to increase attendance at subsidized preschool programs: The Show Up to Grow Up intervention. *Organizational Behavior and Human Decision Processes*, *163*, 65-79.

Katz, M., Johnson, M. C., & Adams, G. (2016). Improving prekindergarten attendance: School-level strategies for messaging, engaging parents, and responding to absences in four DC public schools. Washington, DC: Urban Institute.

Kim, J. S., & Quinn, D. M. (2013). The effects of summer reading on low-income children's literacy achievement from kindergarten to grade 8: A meta-analysis of classroom and home interventions. *Review of Educational Research*, *83*(3), 386–431.

Kim, Y., Montoya, E., Doocy, S., Austin, L. J., & Whitebook, M. (2022). Impacts of COVID-19 on the early care and education sector in California: Variations across program types. *Early Childhood Research Quarterly*, *60*, 348-362.

Kopack Klein, A., Aikens, N., Li, A., Bernstein, S., Reid, N., Dang, M., Blesson, E., Rakibullah, S.,Scott, S., Cannon, J., Harrington, J., Larson, A., Malone, L., & Tarullo, L. (2021). *Descriptive Data on Head Start Children and Families from FACES 2019.* Washington, DC: Office of Planning, Research, and Evaluation.

Kopack Klein, A., Aikens, N., Malone, L., & Tarullo, L. (2018). *A Year in Head Start: Findings from FACES 2014 on Children's Progress Toward School Readiness During the 2014-2015 Program Year*. Washington, DC: Office of Planning, Research, and Evaluation.

Language and Reading Research Consortium, & Chiu, Y. D. (2018). The simple view of reading across development: Prediction of grade 3 reading comprehension from prekindergarten skills. *Remedial and Special Education*, *39*(5), 289-303.

Levine, S. C., Suriyakham, L. W., Rowe, M. L., Huttenlocher, J., & Gunderson, E. A. (2010). What counts in the development of young children's number knowledge?. *Developmental Psychology*, *46*(5), 1309.

Linebarger, D. L., & Walker, D. (2005). Infants' and toddlers' television viewing and language outcomes. *American Behavioral Scientist*, *48*(5), 624-645.

Lipsey, M. W., Puzio, K., Yun, C., Hebert, M. A., Steinka-Fry, K., Cole, M. W., . . . Busick, M. D. (2012). Translating the statistical representation of the effects of education interventions into more readily interpretable forms. Washington, DC: National Center for Special Education Research.

Liu, J., Lee, M., & Gershenson, S. (2021). The short-and long-run impacts of secondary school absences. *Journal of Public Economics, 199:104441.*

Lonigan, C. J., Wagner, R. K., & Torgesen, J. K. (2007). TOPEL: Test of preschool early literacy. Austin, TX: Pro-Ed.

Ludwig, J., & Miller, D. L. (2007). Does Head Start improve children's life chances? Evidence from a regression discontinuity design. *The Quarterly Journal of Economics*, *122*(1), 159-208.

Lynch, K., An, L., & Mancenido, Z. (2022). The impact of summer programs on student mathematics achievement: A meta-analysis. *Review of Educational Research.*

McCormick, M. P., Weissman, A. K., Weiland, C., Hsueh, J., Sachs, J., & Snow, C. (2020). Time well spent: Home learning activities and gains in children's academic skills in the prekindergarten year. *Developmental Psychology*, *56*(4), 710.

Mistry, R. S., Biesanz, J. C., Taylor, L. C., Burchinal, M., & Cox, M. J. (2004). Family income and its relation to preschool children's adjustment for families in the NICHD Study of Early Child Care. *Developmental Psychology*, *40*(5), 727.

Moffitt, T. E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, H., ... & Caspi, A. (2011). A gradient of childhood self-control predicts health, wealth, and public safety. *Proceedings of the National Academy of Sciences*, *108*(7), 2693-2698.

National Association for the Education of Young Children. (2011). Code of ethical conduct and statement of commitment.

National Head Start Association (2022). Early Head Start Facts and Figures.

National Mathematics Advisory Panel. (2008). Foundations for success: The final report of the National Mathematics Advisory Panel. Washington, DC: U.S. Department of Education.

Neitzel, C., & Stright, A. D. (2003). Mothers' scaffolding of children's problem solving: Establishing a foundation of academic self-regulatory competence. *Journal of Family Psychology, 17*(1), 147–159. https://doi.org/10.1037/0893-3200.17.1.147

Nickow, A., Oreopoulos, P., & Quan, V. (2020). The impressive effects of tutoring on prek-12 learning: A systematic review and meta-analysis of the experimental evidence. NBER Working Paper No. 27476.

Paris, S. G. (2005). Reinterpreting the development of reading skills. *Reading Research Quarterly*, 40(2), 184-202. doi: 10.1598/RRQ.40.2.3.

Parker, F. L., Piotrkowski, C. S., Kessler-Sklar, S., Baker, A. J., Peay, L., & Clark, B. (1997). The impact of parent involvement in Head Start on parents and children. Final Report.

Petterson, S. M., & Albers, A. B. (2001). Effects of poverty and maternal depression on early child development. *Child Development*, *72*(6), 1794-1813.

Piasta, S. B., Justice, L. M., McGinty, A. S., & Kaderavek, J. N. (2012). Increasing young children’s contact with print during shared reading: Longitudinal effects on literacy achievement. *Child Development*, *83*, 810–820. doi:10.1111/j.1467-8624.2012.01754.x

Raudenbush, S. W. & Eschmann, R. D., (2015) Does schooling increase or reduce social inequality? *Annual Review of Sociology*, Vol. 41: 443-470.

Robinson, C. D., Chande, R., Burgess, S., & Rogers, T. (2022). Parent engagement interventions are not costless: Opportunity cost and crowd out of parental investment. *Educational Evaluation and Policy Analysis*, *44*(1), 170-177.

Royston, P., & White, I. R. (2011). Multiple imputation by chained equations (MICE): implementation in Stata. *Journal of Statistical Software*, *45*, 1-20.

Sawyer, B. E., Justice, L. M., Guo, Y., Logan, J. A., Petrill, S. A., Glenn-Applegate, K., ... & Pentimonti, J. M. (2014). Relations among home literacy environment, child characteristics and print knowledge for preschool children with language impairment. *Journal of Research in Reading*, *37*(1), 65-83.

Sénéchal, M., & Young, L. (2008). The effect of family literacy interventions on children’s acquisition of reading from kindergarten to grade 3: A meta-analytic review. *Review of Educational Research*, *78*(4), 880-907.

Solomos, J. (2021). Race and ethnicity in pandemic times. *Ethnic and Racial Studies*, *44*(5), 719-734.

Sommer, T. E., Schneider, W., Chor, E., Sabol, T. J., Chase-Lansdale, P. L., Brooks-Gunn, J., ... & King, C. (2020). A two-generation education intervention and children’s attendance in Head Start. *Child Development*, *91*(6), 1916-1933.

Stevenson, D. L., & Baker, D. P. (1987). The family-school relation and the child's school performance. *Child Development*, 1348-1357.

Storch, S. A., & Whitehurst, G. J. (2002). Oral language and code-related precursors to reading: Evidence from a longitudinal structural model. *Developmental Psychology*, *38*(6), 934.

U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP) (2022). 2020 and 2022 Long-Term Trend (LTT) Reading and Mathematics Assessments.

U.S. Department of Health and Human Services, Administration for Children and Families. (2010). Head Start Impact Study: Final Report.

U.S. Department of Health and Human Services. (2015). Head Start early learning outcomes framework: Ages birth to five.

Watts, T. W., Duncan, G. J., Siegler, R. S., & Davis-Kean, P. E. (2014). What's past is prologue: Relations between early mathematics knowledge and high school achievement. *Educational Researcher*, *43*(7), 352-360.

Weiland, C., Greenberg, E., Bassok, D., Markowitz, A., Rosada, P. G., Luetmer, G., ... & Snow, C. (2021). Historic crisis, historic opportunity.

West, M. R., & Lake, R. (2021). How much have students missed academically because of the pandemic? A review of the evidence to date. *Center on Reinventing Public Education*.

Yoshikawa, H., Weiland, C., Brooks-Gunn, J., Burchinal, M. R., Espinosa, L. M., Gormley, W. T., ... & Zaslow, M. J. (2013). Investing in our future: The evidence base on preschool education.

Table 1

Descriptive Statistics

	Enrollee Population	Random Sample	Final Sample					National Sample[a]
	Mean	Mean	Mean	SD	Min	Max	% Missing	
Female	--	--	0.52	0.50	0	1	0%	0.50
Black Non-Hispanic	0.36	0.42	0.36	0.48	0	1	0%	0.33
Hispanic	0.51	0.41	0.46	0.50	0	1	0%	0.35
White/Asian Non-Hispanic	0.11	0.14	0.13	0.33	0	1	0%	0.22
Other Race Non-Hispanic/Race Missing	0.02	0.03	0.05	0.21	0	1	0%	0.10
Age (Months)	--	--	50.82	6.07	36	60	0%	
Age 3 or younger	0.43	0.37	0.29	0.46	0	1	0%	0.49
Age 4 or older	0.57	0.63	0.71	0.46	0	1	0%	0.51
Home language not English	0.39	0.31	0.35	0.48	0	1	0%	0.21
Parent Education								
< High School	0.20	0.17	0.19	0.40	0	1	0%	0.22
High School Diploma	--	--	0.39	0.49	0	1	0%	0.34
Some College / AA Degree	--	--	0.32	0.47	0	1	0%	0.34
BA +	--	--	0.09	0.29	0	1	0%	0.10
Single Parent Household	0.60	0.64	0.64	0.48	0	1	0%	0.64
Number of Days Attended In Person	--	--	88.69	53.63	0	168	0%	
N	1823	600	336					

[a] All statistics in this column except parent education are from Kopack Klein et al. (2021) and weighted to represent all children enrolled in Head Start in fall 2019. Parent education data are weighted to represent all children enrolled in Head Start in fall 2014 (Kopack Klein et al., 2018).

Table 2

Bivariate Correlations Between Study-Administered Assessments

Variable	1	2	3	4	5	6	7	8	9	10
1. Executive Function (Fall)	--									
2. Oral Counting (Fall)	0.15*	--								
3. Number Naming (Fall)	0.20**	0.61**	--							
4. Quantity Comparison (Fall)	0.05	0.05	0.09	--						
5. Print Knowledge (Fall)	0.29**	0.48**	0.63**	-0.01	--					
6. Executive Function (Spring)	0.28**	0.10	0.04	-0.01	0.17**	--				
7. Oral Counting (Spring)	0.22**	0.34**	0.27**	-0.07	0.24**	0.29**	--			
8. Number Naming (Spring)	0.10	0.54**	0.68**	-0.01	0.58**	0.09	0.45**	--		
9. Quantity Comparison (Spring)	0.07	0.62**	0.63**	0.09	0.54**	0.11 +	0.38**	0.60**	--	
10. Print Knowledge (Spring)	0.15*	0.35**	0.54**	-0.02	0.73**	0.28**	0.32**	0.60**	0.46**	--

Note. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Table 3

Descriptive Results of Children's Academic Achievement and Executive Function during the Pandemic-Affected School Year

	Child Outcomes		
	Fall Score Mean (SD)	Spring Score Mean (SD)	Effect Size
Print Knowledge	96.12 (14.91)	100.11 (14.35)	0.27[a]
Oral Counting	11.74 (10.29)	19.02 (15.21)	0.71[b]
Number Naming	16.81 (14.95)	23.51 (17.43)	0.45[b]
Quantity Comparison	7.28 (4.53)	10.48 (4.72)	0.71[b]
Executive Function	97.68 (7.95)	98.42 (6.45)	0.05[a]

Note. [a] Fall-spring score difference divided by the assessment norming sample SD (15).
[b] Fall-spring score difference divided by fall sample SD.

Table 4

Multivariate Results of Children and Parent Outcomes as a Function of In-Person (versus Virtual) Preschool Attendance during the Pandemic-Affected School Year

	Child Outcomes				
	Print Knowledge	Oral Counting	Number Naming	Quantity Comparison	Executive Function
In-person preschool attendance	0.467*	0.459+	0.830**	0.051	0.013
N	242	247	247	247	250
	Parent Outcomes				
			Parent-Child Interactions	Parent-School Trust and Involvement	Parent-Teacher Communication Frequency
In-person preschool attendance			0.017	-0.001	-0.004
N			240	237	239

Note. Separate linear regression models with center fixed effects were estimated for each outcome. All models controlled for child demographics including race, gender, age, English as a home language, parent education, single parent household, and assessment location (home versus school). Child outcome models also controlled for child's fall scores on the five academic outcomes. Parent models include controls for child fall executive function score. Outcomes consist of three parent survey response categories. Robust standard errors displayed. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001.

Figure 1

Histogram of In-Person Preschool Days per Calendar Month Attended among Children who Began the School Year in In-Person Learning (blue); Virtual Learning (Red); and those who Attended at Least One Day of In-Person Preschool ('Ever-attenders') (Green)

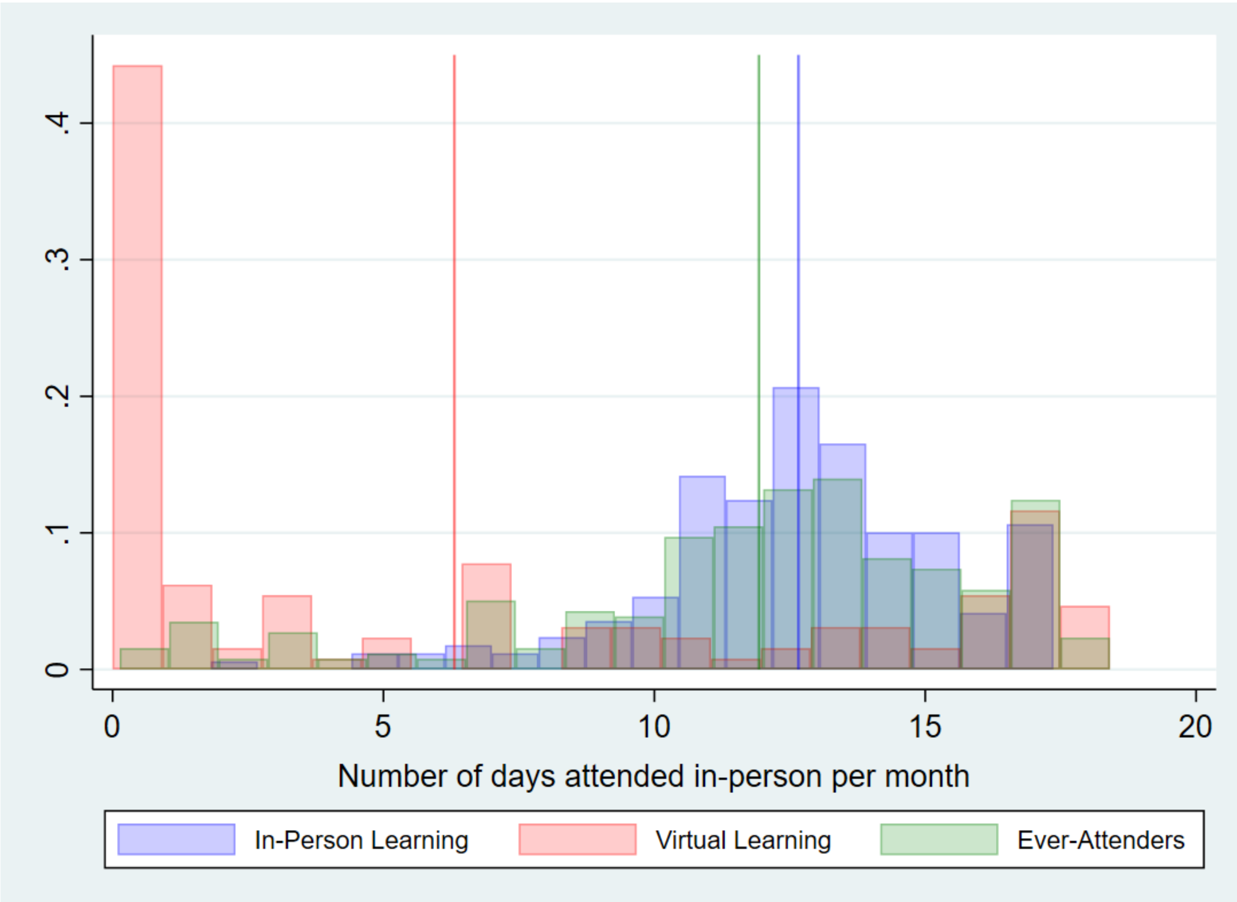
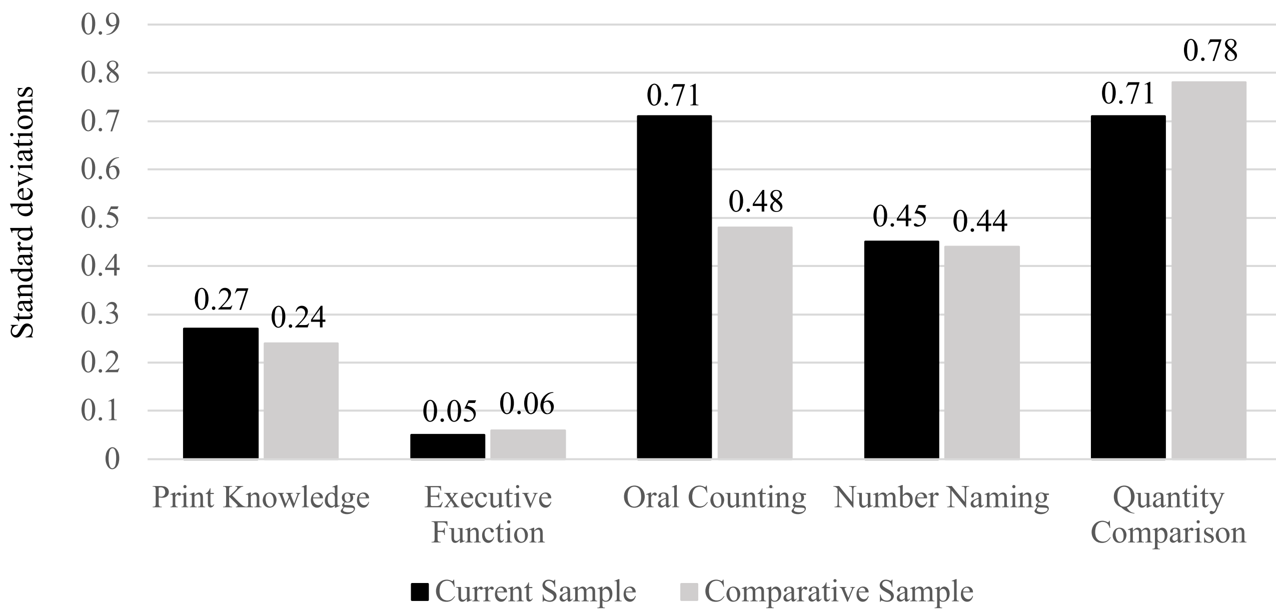


Figure 2

Fall-to-Spring Growth on Direct Assessments of Sample in Current Study with Samples in Comparative Studies



Note: Comparative samples derived from network prior year data (print knowledge); Anderson et al., 2020 (executive function), and Hojnoski et al., 2009 (numeracy indicators).