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

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

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Abstract

The COVID-19 pandemic's impact on preschool children's school readiness skills remains understudied. This research investigates whether exposure to in-person (versus virtual) Head Start preschool predicted 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) experienced low in-person preschool exposure compared to national pre-pandemic norms. However, study children experienced gains during the pandemic-affected year of 0.08 SD in executive function, 0.34 SD in print knowledge, and 0.49-0.75 in early numeracy skills. For two of the three early numeracy domains measured, spring test score outcomes were stronger among children who attended more in-person preschool.

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

Since the onset of the COVID-19 pandemic, children's schooling has suffered large-scale disruptions. In many areas of the United States, including major metropolitan areas such as Boston, Los Angeles, and Washington, D.C., public 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 disruptions have caused students to fall behind academic benchmarks (West & Lake, 2021) and worsened children's social-emotional well-being (Hamilton & Gross, 2021). Learning setbacks have been disproportionately concentrated among children from historically marginalized groups, including Black and Hispanic children, dual language learners, and children with disabilities (e.g., 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 children's development remains understudied. After the initial outbreak in the spring spurred widespread preschool closures, in-person preschool access in many localities was intermittently disrupted throughout the subsequent school year (Weiland et al., 2021). Preschool enrollment declined substantially during the pandemic, particularly among low-income children (Barnett & Jung, 2021). Teachers reported that preschoolers struggled under virtual learning, due to weak remote learning offerings, parents' difficulties supervising online preschool while they worked, and preschoolers' need to learn social skills in-person (Bassok et al., 2021). Parents also reported regressed or worsened home behaviors (Hanno et al., 2022) and increased passive screen time (Gonzalez et al., 2020) during remote learning.

To date, we have little research using direct child assessments to examine learning outcomes for preschoolers and for low-income children during the COVID-19 pandemic. The evidence has been largely limited to teacher and parent surveys, which may suffer from self-report bias. Additionally, 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 addressing the pandemic period is needed to examine how children have fared under a regimen of substantially reduced access to preschool.

Understanding Head Start preschoolers' development during the pandemic is especially important because a human capital perspective predicts that low-income individuals may bear the heaviest burden of disasters (Baez et al., 2010), as multiplier effects exacerbate initial disadvantages (Ceci & Papierno, 2005). Moreover, the interaction of the pandemic with existing racial inequities may disproportionately harm children from communities of color (e.g., Solomos, 2021). Head Start is the largest federal program providing free preschool to low-income children in the United States. We may thus expect Head Start preschoolers' learning trajectories to be significantly harmed by COVID-19. Simultaneously, the compensatory hypothesis posits that universal preschool programs reduce social inequality (Barnett, 1992); thus we may expect in-person Head Start access during the pandemic to mitigate harms to low-income children's development.

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, particularly for children with weaker baseline skills (Ansari & Purtell, 2018). Early print knowledge, numeracy, and executive function are important for kindergarten readiness and later educational attainment (e.g., Clements et al., 2013; Longian et al., 2000; Moffitt et al., 2011); however, the impact of preschool absences on children's executive function is not well understood.

The current research addresses these gaps by investigating the early literacy, numeracy, and executive function development of children in Head Start preschools during the COVID-19 outbreak. We examine whether exposure to in-person (versus virtual) preschool during COVID-19 predicted child outcomes along with parent involvement outcomes.

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, which we classify as exploratory in nature, we aim both to present among the first empirical data from child assessments on this topic, and to stimulate new research in this arena.

Method

Participants

Study participants were a sample of randomly-selected children (N = 336) enrolled in a network of Head Start centers located across four states during the 2020-21 school year. Table S1 presents descriptive information for the study 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 S1 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.

Measures

Academic Achievement

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 (α = 0.88 [publisher-reported]). We assessed *early numeracy* 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; Number Naming measures the ability to identify numerals; and Quantity Comparison indexes the ability to judge differences in the quantity of object groups. Raw scores are used in analyses (publisher-reported test-retest reliability = 0.71-0.88). We assessed *executive function*, including working memory, inhibitory control, and cognitive flexibility, using the Minnesota Executive Function Scale (MEFS; Carlson & Zelazo, 2014). 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 = .93). For both TOPEL and MEFS, we use age-adjusted scores computed using the test developers' guidelines that permit examination of growth over time.

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. This 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 critical 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. 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, who were remote in all cases, 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 then present correlations between child characteristics and in-person preschool attendance.

To examine the relationship between preschool exposure and learning outcomes, we predict 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. Next, we fit a second set of regression models examining relationships between in-person preschool attendance and parent-child interactions, parent-school trust and involvement, and parent-teacher communication, controlling for baseline executive function and demographic indicators. Third, we fit interaction models to examine whether the relationships between in-person attendance and outcomes varied by baseline scores. All models were fit with robust standard errors. As a sensitivity check, we refit all models using multiple imputation to account for missing data (Royston & White, 2011) and report models using standardized beta coefficients, and find the same pattern of findings (see Tables S3 and S4).

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 the TOPEL assessment, the network of Head Start preschools 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.

Factors Associated With Participation in In-Person Preschool

We next examine correlations between child characteristics and in-person preschool attendance (Table 1). Compared to Hispanic children, Black Non-Hispanic children had significantly lower mean in-person attendance. Children whose home language was not English had significantly higher in-person attendance than children whose home language was English. Children who had lower mean fall quantity comparison and executive function scores as well as those with higher mean fall print knowledge scores attended significantly more days in-person. We did not find significant correlations between in-person attendance and parent education, single parent household status, child age, or child gender.

Associations Between Preschool Access and Learning Outcomes During the Pandemic-Affected School Year

Descriptively, study children experienced mean gains in school readiness skills during the pandemic-affected school year (Table 2). In *print knowledge*, study children achieved fall to spring gains that were 0.34 SD greater than expected for their age, with mean scores increasing from the 36th percentile of the test norming sample in the fall to the 50th percentile at spring posttest (Lipsey et al., 2012; Lonigan et al., 2007). In *early numeracy*, study children gained an average of 0.75 SD in oral counting, 0.49 SD in number naming, and 0.65 SD in quantity comparison. In *executive function*, study children experienced growth that was 0.08 SD higher than expected for their age, with average scores increasing from the 43rd percentile of the assessment norming sample in the fall to the 46th percentile in the spring (Carlson & Zelazo, 2017; Lipsey et al., 2012).

Table 3 (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. Children's spring outcomes in print knowledge, quantity comparison, and executive function were not significantly associated with their exposure to in-person preschool in the multivariate models. However, children who attended more in-person preschool during the pandemic year had better learning outcomes on two of the three assessed early numeracy assessments -- oral counting ($b = 0.42$; $p < 0.01$) and number naming ($b = 0.43$; $p < 0.01$).

Table 3 (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. Children who attended more in-person preschool had higher parent-reported parent-child educational interactions; this association was marginally significant ($b= 0.01$; $p < 0.10$). The association between in-person preschool and parents' school trust was not significant. Parents of children who attended more in-person preschool were significantly less likely to report that they communicated with their child's teacher once per week or more ($b = -0.01$; $p < 0.05$), potentially because caregiver assistance was a de facto requirement of the weekly Zoom meetings required by the virtual learning model.

The interaction models show that for most outcomes, relationships between in-person attendance and spring outcomes did not differ significantly by baseline skills. The one exception was number naming, for which the advantages associated with in-person attendance were greater for children with lower baseline skills; this difference was marginally significant (b = -0.02; $p < 0.10$).

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 these relatively low levels of in-person preschool attendance, study children experienced 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 comparisons worth noting.

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, slightly below study children's gains of 0.34 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 0.49-0.75 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 (0.08 SD).

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. We found that although not for print knowledge or executive function, for two of the three early numeracy domains measured, outcomes were stronger among children who attended more in-person preschool. Preschool mathematics is an important foundation for later performance (National Mathematics Advisory Panel, 2008; Duncan et al., 2007), suggesting that children who missed preschool time during the pandemic may benefit from support for missed numeracy learning opportunities. The benefits of in-person preschool on number naming skills were marginally greater for children with weaker baseline skills, aligned with theories of in-person preschool as compensatory (Barnett, 1992) and with research documenting that online learning has disproportionately negative impacts for K-12 students with lower baseline achievement (Ahn & McEachin, 2017).

Strengthening parents' educational involvement is a central goal of Head Start (Sacerdote, 2007; Todd & Wolpin, 2003). We found a marginally significant, positive relationship between in-person preschool attendance during the pandemic-affected year and parent-child educational interactions. This link, while non-causal, is consistent with prior research (e.g., Love et al., 2005; Zhai et al., 2013) which found that Head Start increased parents' involvement across a range of domains, perhaps via direct encouragement or because childcare freed parents' time for home-learning activities (Gelber & Isen, 2013).

Our findings point towards several promising avenues for future research. First, the findings provide an existence proof for 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. Future comparative studies of in-person versus virtual assessment conditions, benefits, and costs are warranted. Nevertheless, even if virtual assessments are not perfect, they were a critical tool during the pandemic, and they may well be needed in future situations where schooling is disrupted. We argue that researchers and practitioners cannot simply forego assessing children in extended public health emergency situations when in-person testing is precluded. Early screening is critical for identifying children at risk of developmental difficulties, and for determining early interventions. Foregoing assessments risks the chance of undiagnosed developmental delays which could have long-lasting impacts through children's lifespans.

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), virtual preschool affects the ecology of the family, including parents' ability to work and family stress. 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 communicating attendance goals with parents, fostering parent relationships, text messaging families about attendance, and engaging community partners show promise (Kalil et al., 2021; Katz et al., 2016; Sommer et al., 2020). Moreover, providing children with opportunities for more instructional time, such as tutoring (e.g., Nickow et al., 2020) and summer programs (Kim & Quinn, 2013; Lynch et al., 2021), is a research-based avenue to support children's progress.

In summary, this brief aims to spur future research on preschoolers' experiences during COVID-19, particularly using direct child assessments. Despite the noted limitations, we compiled some of the first known evidence from direct child testing on preschoolers' learning during the pandemic. 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.

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Table 1

Bivariate Correlations with In-Person Preschool Attendance During the Pandemic-Affected School Year

	Bivariate Correlation (Attendance)	
Days Attended In-Person		
Print Knowledge		
Fall	0.12	*
Spring	0.11	+
Oral Counting		
Fall	-0.03	
Spring	0.14	*
Number Naming		
Fall	0.09	
Spring	0.12	+
Quantity Comparison		
Fall	-0.11	*
Spring	0.01	
Executive Function		
Fall	-0.11	*
Spring	-0.01	
Parent-Child Interactions	0.04	
Parent School Trust and Involvement	0.03	
Parent-Teacher Communication 1x + Week	-0.18	**
Female	-0.01	
Black Non-Hispanic	-1.76	*
Hispanic	†	
White/Asian Non-Hispanic	-0.09	
Other Race Non-Hispanic/Race Missing	0.57	
Age (Months)	-0.08	
Home Language Not English	0.13	*
Parent Education		
< High School	†	
HS Diploma	-0.723	
Some College / AA Degree	-0.742	
BA +	0.059	
Single Parent Household	0.04	

Note: Pearson's correlation coefficients. Regression coefficients shown for categorical variables.
† Omitted reference category.
+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001.

Table 2

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	94.79 (14.66)	99.82 (14.60)	0.34[a]
Oral Counting	11.42 (9.95)	18.86 (14.83)	0.75[b]
Number Naming	16.13 (14.41)	23.24 (17.44)	0.49[b]
Quantity Comparison	7.58 (4.39)	10.45 (4.76)	0.65[b]
Executive Function	97.17 (8.89)	98.34 (6.39)	0.08[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 3

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
Main effects of in-person preschool attendance	0.081	0.421**	0.426**	-0.016	0.065
In-person preschool x Baseline skills[a]	-0.004	0.018	-0.018+	0.015	-0.002
N	242	247	247	247	250
	Parent Outcomes				
			Parent-Child Interactions	Parent-School Trust and Involvement	Parent-Teacher Communication Frequency
Main effects of in-person preschool attendance			0.015+	0.005	-0.012*
In-person preschool x Baseline executive function			-0.001	0.002	0.000
N			241	238	240

Note. Separate linear regression models were estimated for each outcome. Main effects models were fit without interaction terms. Interaction models add the interaction term to main effects models. 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. [a]Interaction term is with baseline skills in the same subject as the outcome variable. [b]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)

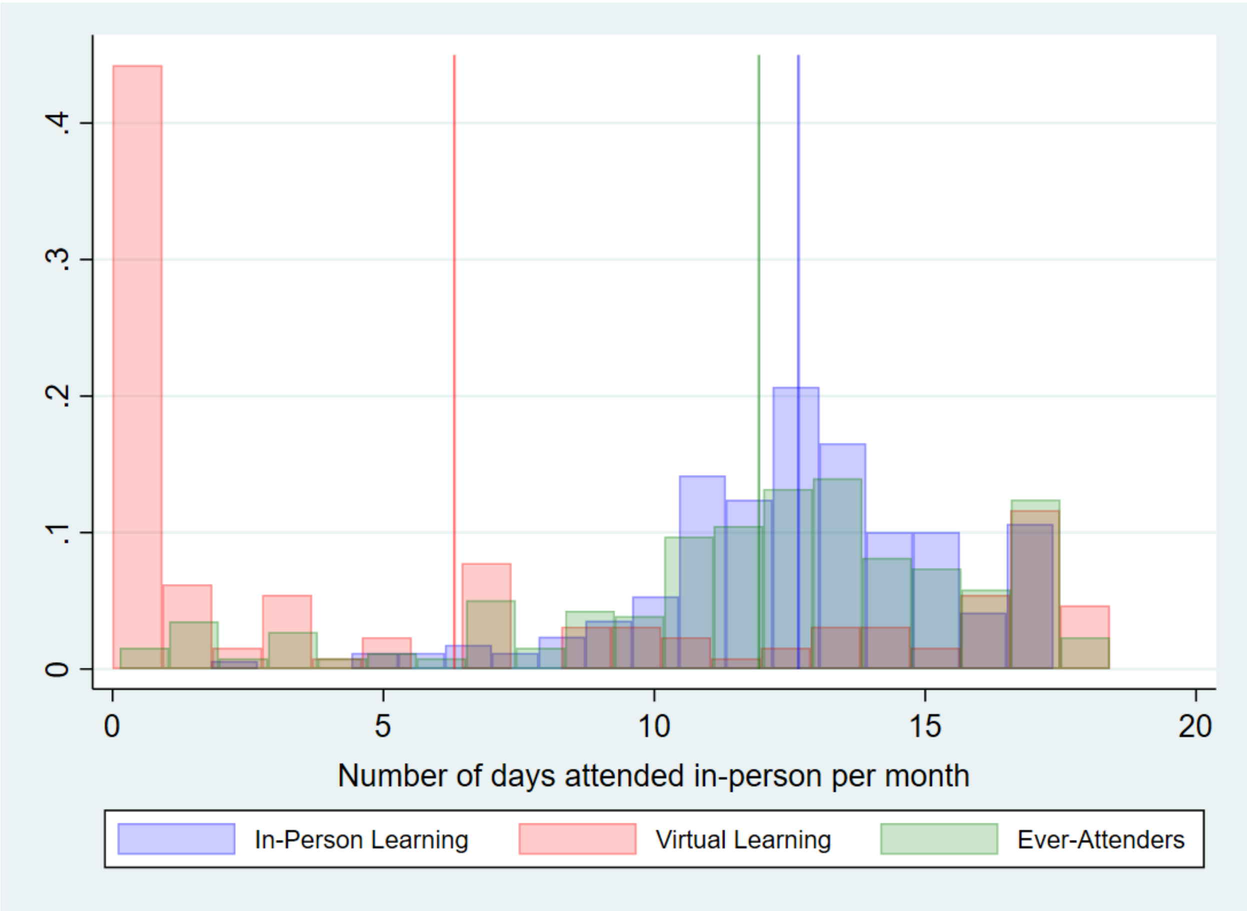
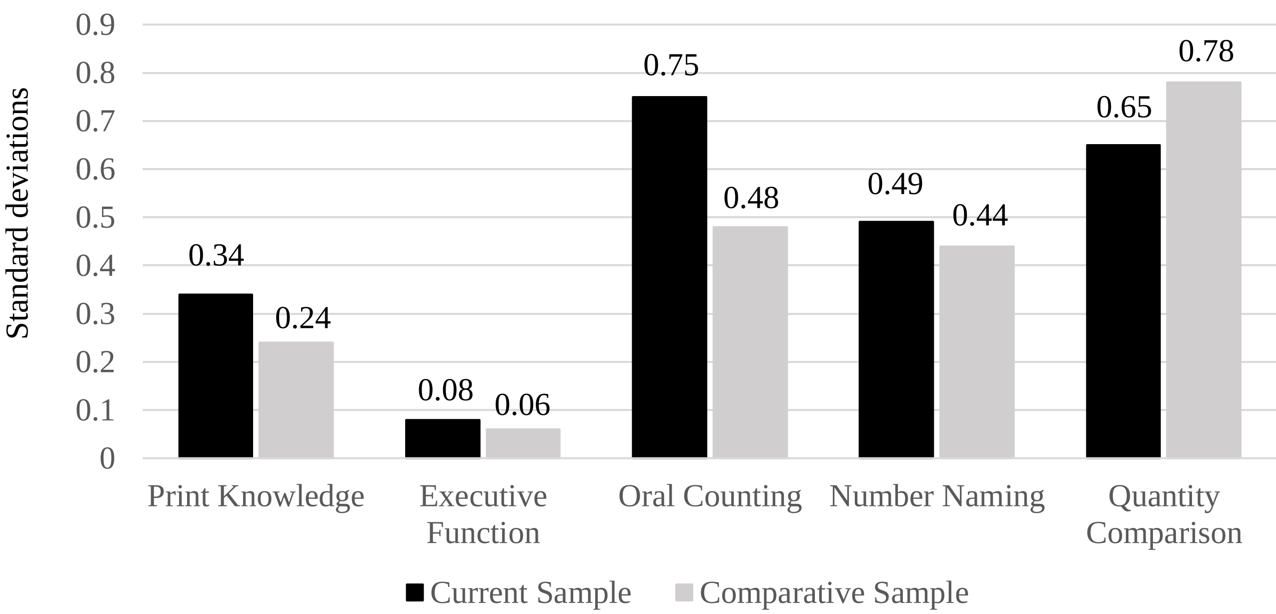


Figure 2

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).

Online Appendix

Table S1

Full Descriptive Statistics

	Mean	SD	Min	Max	% Missing	Bivariate Correlation (Attendance)		National Sample[a]	SD
Number of Days Attended In Person	88.69	53.63	0	168	0%				
Print Knowledge, Fall	94.79	14.66	70	144	6%	0.12	*		
Print Knowledge, Spring	99.82	14.60	65	144	20%	0.11	+		
Oral Counting, Fall	11.42	9.95	0	60	2%	-0.03			
Oral Counting, Spring	18.86	14.83	0	85	18%	0.14	*		
Number Naming, Fall	16.13	14.41	0	63	3%	0.09			
Number Naming, Spring	23.24	17.44	0	60	18%	0.12	+		
Quantity Comparison, Fall	7.58	4.39	0	20	2%	-0.11	*		
Quantity Comparison, Spring	10.45	4.76	0	22	18%	0.01			
Executive Function, Fall	97.17	8.89	61	126	7%	-0.11	*	95.6	10.3
Age 3 and Under	96.23	9.39	61	120				94.7	11.2
Age 4 and Over	97.56	8.67	61	126				96.4	9.4
Executive Function, Spring	98.34	6.39	80	114	18%	-0.01			
Age 3 and Under	97.34	6.47	81	113					
Age 4 and Over	98.77	6.33	80	114					
Parent Child Interactions	0.00	0.69	-2.01	0.87	23%	0.04			
Parent School Trust and Involvement	-0.02	0.80	-4.07	0.40	24%	0.03			
Parent-Teacher Communication 1x + Week	0.77	0.42	0	1	23%	-0.18	**		
Female	0.52	0.50	0	1	0%	-0.01		0.50	
Black Non-Hispanic	0.36	0.48	0	1	0%	-1.764	*	0.33	
Hispanic	0.46	0.50	0	1	0%	†		0.35	
White/Asian Non-Hispanic	0.13	0.33	0	1	0%	0.574		0.22	
Other Race Non-Hispanic/Race Missing	0.05	0.21	0	1	0%	0.04		0.10	
Age (Months)	50.82	6.07	36	60	0%	-0.08			
Age 3 or younger as of Sept. 1	0.29	0.46	0	1	0%	0.09	+	0.49	
Age 4 or older as of Sept 1	0.71	0.46	0	1	0%	-0.09	+	0.51	

Home Language Not English	0.35	0.48	0	1	0%	0.13	*	0.21
Parent Education								
< High School	0.19	0.40	0	1	0%	†		0.22
High School Diploma	0.39	0.49	0	1	0%	-0.723		0.34
Some College / AA Degree	0.32	0.47	0	1	0%	-0.742		0.34
BA +	0.09	0.29	0	1	0%	0.059		0.10
Single Parent Household	0.64	0.48	0	1	0%	0.04		0.64

*Note*s. For bivariate correlations, + p<0.10 * p<0.05 ** p<0.01 *** p<0.001.
[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).
[†] Reference category.

Table S2

Items Included in Survey Scales Used in Analysis

	Items
Parent-Child Educational Interactions	Last week, HOW MANY TIMES did you do each of the following activities with your child? It's OK if you didn't do these things at all last week. Each week is different. Just answer as accurately as you can. *Choice options: None – Once – Twice – More than twice* • Paused to connect with your child before starting an activity (for example, taking a deep breath together) • Used "open-ended" questions during activities with your child (questions that can't be answered with a "yes" or a "no") • Let your child make a mistake or have to do something more than once in order to succeed at a task or activity • Talked with your child about an activity after you completed it (For example, did he or she like it, how did it make him/her feel, what else did he/she think about it) • Increased the difficulty of an activity that your child had already mastered to make it more challenging for him/her
Parent-School Trust and Involvement	Please answer the following questions with the answer that fits your experience best. Select only one response. *Choice options: Never – Sometimes – Half the time – Most of the time – Always* • My Center gives me opportunities to contribute to our Center by planning or leading activities, sharing ideas or working together with other families to support our children's school readiness. • My teachers keep me informed about my child's progress and events at the school and actively solicit my support to enhance his/her learning at home. • When I raise concerns about what is happening in my child's classroom, I feel my feedback is handled respectfully. I am satisfied with the outcome of the discussion. • I trust that [the center] is doing everything it can to make sure my child will be ready for kindergarten.
Parent-Teacher Communication Frequency	In an average week, how many times did you communicate with your child's teacher? Please count all ways of communicating listed above [Regular phone call, Video call, Remind/Class Dojo, Regular texting].

	Choice options: Twice a week or more – Once a week – Every other week – Hardly ever (once a month or less) – Not at all

Table S3

Missing Data Analysis: Replication of Multivariate Results of Children and Parent Outcomes as a Function of In-Person (versus Virtual) Preschool Attendance during the Pandemic-Affected School Year Using Multiple Imputation

	Child Outcomes				
	Print Knowledge	Oral Counting	Number Naming	Quantity Comparison	Executive Function
Main effects of in-person preschool attendance	0.152	0.374**	0.409**	-0.004	0.031
In-person preschool x Baseline skills[a]	-0.001	0.009	-0.016 +	0.010	0.001
N	336	336	336	336	336
			Parent Outcomes		
			Parent-Child Interactions	Parent-School Trust and Involvement	Parent-Teacher Communication Frequency
Main effects of in-person preschool attendance			0.020**	0.001	-0.010**
In-person preschool x Baseline executive function			-0.001	0.001	0.000
N			336	336	336

Note. Separate linear regression models were estimated for each outcome, using multiple imputation. Main effects models were fit without interaction terms. Interaction models add the interaction term to main effects models. 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. [a]Interaction term is with baseline skills in the same subject as the outcome variable. [b]Outcomes consist of three parent survey response categories. Robust standard errors displayed. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001.

Table S4

Standardized Coefficients in Replication of 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
Main effects of in-person preschool attendance	0.031	0.150**	0.133**	-0.019	0.055
In-person preschool x Baseline skills[a]	-0.138	0.182	-0.223+	0.219	-0.200
N	242	247	247	247	250

	Parent Outcomes		
	Parent-Child Interactions	Parent-School Trust and Involvement	Parent-Teacher Communication Frequency
Main effects of in-person preschool attendance	0.114+	0.032	-0.154*
In-person preschool x Baseline executive function	-0.879	1.013	0.371
N	241	238	240

Note. Standardized beta coefficients shown. Separate linear regression models were estimated for each outcome. Main effects models were fit without interaction terms. Interaction models add the interaction term to main effects models. 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. [a]Interaction term is with baseline skills in the same subject as the outcome variable. [b]Outcomes consist of three parent survey response categories. Robust standard errors displayed. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001.