Following the Preschool Boost into Third Grade: Do Public Preschool Benefits on Cognitive and Self-Regulatory Skills Persist?

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Abstract

One of the most vexing challenges in early childhood developmental research is the "fade out" of preschool benefits: preschool attenders tend to outperform non-attenders on basic literacy and math outcomes at the end of preschool, but scores between the two groups often converge by the end of kindergarten. There are two shortcomings of this research: first, most studies have relied on a relatively narrow band of literacy and math measures to assess preschool impacts, leaving out a broader range of cognitive skills and ignoring the domain of self-regulation entirely. Second, the few studies that have included broader-band outcomes have only followed children to first grade, with one exception that followed children to third grade, but produced a confusing set of mixed findings and did not assess self-regulation. Thus, a complete picture of the potential impacts of preschool attendance remains unknown. The current study tests for sustained preschool benefits in third grade (N=694, $M_{age\ \text{at}\ 3rd}$=8.5 years) on an unprecedented set of directly assessed language and math skills as well as multiple dimensions of self-regulation. In our racially and ethnically diverse sample of low-income children attending the nation's two largest public preschool programs – Head Start and school-based public pre-k – in Tulsa, OK, preschool attenders outperformed non-attenders on numeracy and self-regulatory skills in third grade. Consistent with prior studies, the preschool advantage on basic literacy disappeared, and the advantage on applied problem-solving and language skills weakened to marginal levels of significance.

Keywords: public preschool; preschool; Head Start; pre-k; elementary school.

Following the Preschool Boost into Third Grade:

Do Public Preschool Benefits on Cognitive and Self-Regulatory Skills Persist?

Over the past two decades, nearly 20 preschool evaluation studies have documented immediate positive benefits of attending one of the nation's two largest public preschool programs – public school-based pre-k or Head Start – on children's cognitive outcomes (Ansari et al., 2020; Barnett et al., 2018; Gormley et al., 2005, 2008, 2011; Haslip, 2018; Henry et al., 2006; Jenkins et al., 2016, 2018; Lipsey et al., 2018; McCormick et al., 2021; Peisner-Feinberg et al., 2014; Puma et al., 2012; Weiland & Yoshikawa, 2013; Winsler et al., 2008; Wong et al., 2008). Immediate benefits are those measured immediately post-preschool: at the end of the preschool year or the start of kindergarten. Of these studies, only two (the Head Start Impact Study [HSIS; Puma et al., 2012]; the Tennessee Voluntary Pre-k evaluation [Lipsey et al., 2018]) continued to follow children *beyond* kindergarten using the same rich, repeated, research-based measures of developmental outcomes (as opposed to school district or state test scores) over time. Both studies found "fade out" of preschool benefits, whereby preschool attenders' and non-attenders' scores converged during and after kindergarten.

Yet it is difficult to draw conclusions about the duration of preschool impacts when the bulk of the literature is limited by the scope of outcomes considered to date. Specifically, most evaluations have included a relatively narrow band of basic literacy skills such as letter-word identification and phonological awareness. These are considered "constrained" or finite skills that, once acquired, do not continue to grow and are often mastered in kindergarten regardless of preschool attendance. Emerging research suggests these are precisely the skills least likely to show enduring impacts of preschool because, while preschool attenders may acquire these skills earlier than non-attenders, the non-attenders acquire them – and thus "catch up" – in

kindergarten. In contrast, "unconstrained" skills that do not have a ceiling and continue developing after preschool ends (and beyond), such as vocabulary and reading comprehension (Snow & Matthews, 2016), are more likely to show preschool impacts that sustain statistical significance, albeit weaking in size over time (McCormick et al., 2021;Weiland et al., 2021). The instruction and practice provided by exposure to preschool may give attenders an early boost (Bailey et al., 2017; Authors et al., *under review*; McCormick et al., 2021), which translates into an enduring advantage over time because non-attenders, even at the same rate of growth, are unable to catch up (e.g., Bailey et al., 2017; Snow & Matthews, 2016). To the extent that prior preschool evaluations have neglected these skills, they may have underestimated lasting benefits.

With respect to math, the constrained/unconstrained distinction has been used far less frequently and consistently because the most commonly used math task in preschool evaluation research – the Woodcock-Johnson test of applied problems (WJ AP; Woodcock et al., 2001) – is a generalized math achievement test that blends constrained (e.g., counting) with unconstrained (e.g., conceptual reasoning) skills (McCormick et al., 2021; Rittle-Johnson et al., 2015). The WJ AP also relies on both math and language skills, which compromises efforts to draw conclusions about pure math skills. Thus, little is known about whether preschool affects the development of *specific* math skills that continue to develop through the elementary grades, predict later math achievement, and that are uncontaminated with language abilities. Numerical fluency – rapid evaluation of relations between numbers – is a specific math skill thought to be a core foundation on which more complex math skills build (Merkley & Ansari, 2016; Schneider et al., 2016).

Recent evidence on preschool impacts confirms the importance of distinguishing among different language and math skills. Specifically, the outcomes of preschool attenders have been documented to converge *less* with the outcomes of non-attenders – that is, non-attenders are

slower to catch up to attenders – on unconstrained language skills and on more specific measures of math than WJ AP. Preschool attenders maintain a significant advantage over non-attenders, although the size of that advantage weakens over time, at the end of kindergarten (Ansari et al., 2020; McCormick et al., 2021) and in first grade (Author et al., *under review*; Lipsey et al., 2018; Puma et al., 2012). The Boston pre-k study, which used a school district measure of oral reading fluency – an unconstrained skill –from first to second grade only, also found a sustained benefit of pre-k attendance that weakened in size but remained significant at second grade (Weiland et al., 2021). However, the Tennessee study found that pre-k impacts on unconstrained language skills (expressive vocabulary; oral comprehension) either became non-significant or remained significant but favored non-attenders, after first grade; impacts on specific measures of math (and WJ AP) were not significant in third grade (Lipsey et al., 2018). This confusing mix of findings underscores the urgent need for additional research to decipher the specific skills on which preschool attenders sustain significant advantages, and for how long. This is the present study's goal.

Prior studies have also largely neglected the critically important developmental domain of self-regulation. Self-regulation is a cornerstone of development because it includes abilities to regulate attention, emotion, and behavior that, in turn, shape children's academic performance, social skills, and mental health (e.g., Shonkoff & Phillips, 2000; Spiegel et al., 2021). Landmark studies that found positive impacts of model preschool programs initiated in the 1960s and 1970s on adult economic outcomes have hypothesized that these lasting effects were driven by interim benefits to self-regulation (Heckman et al., 2010; McCoy et al., 2019). Similarly, authors of recent examinations of longer-term public pre-k impacts on middle school (Durkin et al., 2022) and high school (Amadon et al., 2022) academic outcomes in Tennessee and Tulsa, Oklahoma

respectively have highlighted the importance of measuring self-regulation skills in preschool research. Yet only four contemporary studies of at-scale public preschool programs have done so. Three reported positive effects on inhibitory control, cognitive flexibility, and working memory in kindergarten (Ansari et al., 2021; Peisner-Feinberg & Schaaf, 2011; Weiland & Yoshikawa, 2013). One found no such effects in kindergarten or first grade, albeit using different measures (Author et al., *under review*). Because these studies have not assessed preschool benefits to self-regulation *beyond* kindergarten or first grade, questions remain about the longer-term persistence of these impacts. We aim to address those questions.

Using data from a longitudinal evaluation of public preschool serving 4-year-olds from low-income families in school-based pre-k and Head Start classrooms in Tulsa, OK, this study tests whether the benefits of preschool attendance on an expanded set of both cognitive and self-regulatory outcomes are evident in third grade. These outcomes include unconstrained language skills and specific math skills that may be more likely than previously measured outcomes to demonstrate sustained significant preschool benefits as children age. Our study is also the first contemporary evaluation of Head Start and public pre-k to test for preschool benefits on self-regulation in third grade. If we find that attending public preschool – in school-based pre-k, Head Start, or both – provides a sustained boost to self-regulatory skills in third grade, it will imply that inattention to this domain of outcomes may have led to underestimates of the enduring impacts of public preschool education. As national debates about optimal investments for scarce early education funding continue, this evidence is essential.

Method

Setting and Sample

Data are drawn from the Tulsa School Experiences and Early Development (SEED) Study, an ongoing longitudinal study investigating the preschool and elementary school experiences of children growing up in low-income contexts. Children in the Tulsa Public Schools (TPS) district who were considered low-income (family income below 185% of federal poverty level or received public benefit in last year) were enrolled in the study at age 3 (2016; *n*=611), age 4 (academic year 2017-2018; *n*=687), or in kindergarten (academic year 2018-2019; *n*=130). Recruitment strategies differed slightly across waves to capture a range of preschool experiences and are described in more detail elsewhere (Author et al., 2022; Author et al., *under review*). At age 4, the pre-kindergarten year, children in our study attended public preschool in one of two setting types: school-based pre-k in a TPS public or public charter school, or Head Start at a Community Action Program (CAP) Tulsa Head Start center (34 4-year-olds in our sample attended an Educare Early Childhood School program; given its programmatic alignment with Head Start, we include those children in our Head Start group).

In the kindergarten year, we recruited children who had not attended TPS pre-k, CAP Head Start, Educare, or another center-based preschool the previous year. Candidate families were identified based on school records, and research staff sent recruitment materials home in backpacks and went to school events to meet parents in person. A parent-reported screener questionnaire ensured that children had not enrolled in any preschool programs the previous year and were instead in the care of a parent or another relative. The [name blinded] Institutional Review Board approved all study protocols.

In total, in the fall of third grade, the study sample included 805 children who were directly assessed on our outcome measures in the fall. Because the current analysis compares children who attended preschool in either one of the two public preschool programs - TPS pre-k

or Head Start - to those who stayed home with a parent or relative and did not attend any public or center-based preschool in the preschool year, we excluded 34 children who were not in one of these arrangements within the TPS district at that age, as well as 27 children who moved between these arrangements during the preschool year. We excluded another 28 children who had entered the study at age 3 but by the preschool year had a family income that exceeded 185% of the federal poverty line, and another 22 children because they were not assessed in third grade. The final analytic sample for the current study thus included 694 children. Of these, 525 (76%) attended TPS pre-k, 117 (17%) attended Head Start (or Educare), and 52 (7%) were preschool "non-attenders" who had been cared for by a parent or relative at home in the preschool year.

Children in the analytic sample were racially and ethnically diverse (Table 1): 54% were Hispanic/Latinx, 20% were Black, 6% were Native American, 11% were White, 9% were multiracial, and 1% belonged to another racial/ethnic group. About half (51%) were dual language learners (DLLs), defined as living in a household where a language besides English was spoken, and 7% had an Individualized Education Plan (IEP) in preschool. Half (50%) of mothers were married at the time of the child's birth, and households had 4-5 members on average. Additional sample descriptive statistics appear in Table 1. This study was not pre-registered; data are not yet publicly available.

Measures

English Literacy and Language Skills

We collected two measures of children's constrained English literacy skills – letter-word identification and phonological awareness – as well as of two unconstrained language skills: expressive vocabulary and passage comprehension. Only English answers were accepted, but

bilingual children (assessed by trained bilingual assessors) were prompted once per item if they responded in Spanish. Raw scores were selected for all measures.

Letter-Word Identification. Letter-word identification skills – a measure of print recognition and letter-sound correspondence – were assessed using the Woodcock-Johnson (WJ) Letter-Word Identification (LWID) subtest (Woodcock et al., 2001). This measure asks children to accurately identify letters and to correctly pronounce sight words. Test developers report internal consistency of r=0.96 for children in our study's age range (Woodcock et al., 2001).

Phonological Awareness. Phonological awareness was assessed using the Clinical Evaluation of Language Fundamentals (CELF) - Phonological Awareness supplement (Semel et al., 2003), which measures five phonological skills: syllable blending, syllable segmentation, rhyme detection, phoneme identification, and phoneme blending. Each skill test included a trial and five items; children received a point for each correct item. Within each skill score, children who failed trials were assigned a score of two standard deviations (SD) below the mean on that skill or, if two SD was less than zero, a score of zero. For analyses, a raw total score was created that summed scores across all five skills (α=.71).

Expressive Vocabulary. Expressive vocabulary was assessed using the CELF Expressive Vocabulary subtest, which asked children to label pictures (e.g., a tree branch, with target responses of branch, tree limb, or limb). For children who failed trial items, we assigned a score of two SD below the mean. For children in our study's age range, the reported reliability coefficients are r=0.85-0.91 (Semel et al., 2003).

Passage Comprehension. Passage comprehension was assessed using the WJ Passage Comprehension subtest (Woodcock et al., 2001). In this task, children read a written passage and

were asked to identify a missing key word. Test developers report internal consistency of r=0.93 for children in our age range (Woodcock et al., 2001).

Math Skills

We assessed children's generalized math skills using the WJ AP subtest, the measure of math conventionally used in preschool evaluation research, as well as a specific math skill: numerical fluency. Both were administered in English but correct answers were accepted in Spanish.

Applied Problems. The WJ AP subtest (Woodcock et al., 2001) measured children's mathematical problem-solving ability by asking them to solve computational word problems (e.g., "how many dogs are in this picture?"), and to perform basic addition and subtraction. Test developers report high internal consistency (r =0.92) for children in our study's age range (Woodcock et al., 2001). Raw scores were selected.

Numerical Fluency. Numerical fluency was measured with the Symbolic Numeral Comparison subtest from the Numeracy Screener, a paper-pencil task designed by Lyons et al. (2018). This task measures the efficiency with which children can access the underlying meaning of number symbols. Each item in this task consisted of two symbolic numerals (1-9) presented side-by-side; 48 items (12 per page) were presented. Participants were told, "In this task, your job is to decide which of the two numbers is bigger. Mark the box with the number that means the most things." Children completed as many items as they could within one minute. Scores were calculated as the number of correct responses minus the number of incorrect responses to adjust for guessing.

Self-regulation

We assessed three key dimensions of children's self-regulatory skills: cognitive flexibility, inhibitory control, and working memory.

Cognitive Flexibility. Cognitive flexibility was assessed using the NIH Toolbox (NIHT; Zelazo et al., 2013) Dimensional Change Card Sort task. Children were asked to match pictures on a single feature (e.g., color, shape), and then to periodically switch to another dimension. Scoring is based on accuracy (how often pictures are matched correctly) and reaction time. Uncorrected standard scores – recommended for examining growth over time – were used in all analyses. The test has high test-retest reliability (ICC=.92; Zelazo et al., 2013).

Inhibitory Control. The NIHT Flanker Task was used to measure inhibitory control. Children were instructed to focus on a central stimulus (a picture of a fish) flanked by pictures of other fish, and to select the direction that the central stimulus was facing, both when it was and was not facing the same direction as the flanker fish on either side. Scoring is based on accuracy and reaction time; standard scores were used. The test has high test-retest reliability (ICC=.92; Zelazo et al., 2013).

Working Memory. Children's working memory was assessed using the Test of Memory and Learning (TOMAL) Letters Forward, Letters Backward, and Digits Forward supplementary subtests (Reynolds & Voress, 2007). For each subtest, the assessor read the child progressively longer lists of letters or digits, and the child was required to recite the list back to the assessor; in the case of Letters Backward, the child had to recite the list in the opposite order. The proportion correct was calculated and averaged across subtests (α=0.67).

Covariates

Drawing on a mix of parent-report and school or program administrative data, we included the following covariates: child race/ethnicity (Hispanic/Latinx, Black, White, or

multiracial/another race which, due to small sizes, combined children who were Asian American, Native American, Native Hawaiian, or Pacific Islander); child gender (female=1); child DLL status; maternal education (any post-secondary education=1); maternal employment status (full- or part-time=1); mother's marital status at child's birth (unmarried=1); mother's age at child's birth; and household size, log of household income, and child age at the start of preschool. Missing covariate data ranged from 9% (household size) to 30% (maternal employment). We imputed missing covariate data using imputation with chained equations via the *mi estimate* suite of commands in Stata v. 17; 25 imputed data sets were created and estimates and standard errors were combined across imputed data sets using Rubin's Rules.

Analytic Approach

To estimate the association between preschool attendance and children's outcomes in third grade, we used a propensity score weighting approach. First, we capitalized on non-parametric machine learning techniques via the TWANG routine (Griffin et al., 2014) to estimate propensity scores, defined as the likelihood of a given child attending versus not attending preschool, conditioned on observed covariates. TWANG's algorithms provide optimal specification of the propensity score based on available covariates because they automatically account for interactions and non-linearities in the prediction of the propensity score (Lee et al., 2010; Westreich et al., 2010). The two sets of propensity scores (one for children who attended TPS pre-k and one for children who attended Head Start) were calculated separately in TWANG, following the recommendation of McCaffrey et al. (2013).

The resulting propensity scores were used to create weights, referred to as inverse probability of treatment (IPT) weights. As with the propensity scores, weights were created separately for the two preschool attender groups. Preschool attenders were weighted to resemble

the comparison group of preschool non-attenders. For children who attended TPS pre-k, the IPT weight was calculated as follows:

$$w_i ATC = \frac{1-\hat{p}_i}{\hat{p}_i}$$

where $\hat{p}_i$ is the propensity score, or probability that child *i* attended TPS pre-k, and 1-$\hat{p}$ is the probability that the child did not attend TPS pre-k or Head Start. The same IPT weight was calculated for children who attended Head Start, except that $\hat{p}$ is the probability that the child attended Head Start, and 1-$\hat{p}$ is the probability that the child did not attend TPS pre-k or Head Start. This approach to weighting allowed us to estimate the average treatment effect for the control group (ATC), which approximates the treatment effect on the comparison group *had they received the treatment*, instead of averaging the effects of preschool over the entire sample. This ATC was calculated separately for the two treatment groups to generate unique estimates for TPS pre-k and Head Start.

The TWANG package compares the distribution of covariates across the three groups (TPS pre-k, Head Start, and non-attenders) before and after applying IPT weights. To the degree that these characteristics are similar, post-weighting, between the TPS pre-k attender and comparison non-attender group, and between the Head Start attender and comparison non-attender group, balance is achieved (Austin & Stuart, 2015). Table 2 presents descriptive data on covariates by preschool attender status before and after IPT weighting. Covariate differences between attenders and non-attenders were dramatically reduced after weighting. The standardized difference in weighted covariate means for all covariates across the TPS pre-k vs. non-attender group groups was less than .25, the field's standard threshold for balance (Stuart et al., 2013). Across the Head Start vs. non-attender groups, the standardized difference in weighted

covariate means exceeded .25 for two of the 10 covariates: child race/ethnicity and mother's age at child's birth.

To minimize the threat of bias introduced by this remaining imbalance, our primary results were generated from "doubly robust" regressions (Funk et al., 2011). That is, regression models included IPT weights and also adjusted for all covariates used in the prediction of the propensity scores, an approach commonly used in recent preschool evaluations (Ansari et al., 2021; Hill et al., 2015; Weiland et al., 2021). This is particularly useful given the residual imbalances between Head Start and the non-attender groups on the two covariates (child race/ethnicity, maternal age at child's birth) in Table 2. For all analyses, separate models were run for each third grade outcome comparing each preschool attender group (TPS pre-k; Head Start) to non-attenders. All coefficients were standardized so that results may be interpreted as effect sizes.

Results

Table 3 shows that children who attended TPS pre-k did not outperform preschool non-attenders on LWID and phonological awareness in third grade. However, they scored approximately one-third of a standard deviation (SD) higher on expressive vocabulary (β =.33, *SE* =.16, p =.05), although this effect was only marginally statistically significant. They also scored one-third of a SD higher on passage comprehension (β =.30, *SE* =.16, p =.07), although again with marginal (p<.10) statistical significance. TPS pre-k attenders did not significantly outscore non-attenders on WJ AP. However, they scored approximately half a SD higher on numerical fluency (β=.46, *SE*=.18, p =.01). On measures of self-regulation, TPS pre-k attenders significantly outscored non-attenders by one-third of a SD on both inhibitory control (β =.37, *SE* =.17, p =.03) and working memory (β =.32, *SE* =.15, p =.04), but not on cognitive flexibility.

Children who attended Head Start did not score statistically significantly higher than preschool non-attenders on LWID or phonological awareness in third grade. Neither did they score statistically significantly higher on expressive vocabulary. However, similar to the TPS pre-k attenders, Head Start attenders scored approximately one-third of a SD higher than non-attenders on passage comprehension, but at a marginal level of statistical significance (β =.38, *SE* =.21, *p* =.07). Children who attended Head Start scored one-third of a SD higher than preschool non-attenders on WJ AP in third grade, but only at a marginal significance level (β =.39, *SE* =.24, *p* =.09). Head Start attenders also scored approximately three-quarters of a SD higher than non-attenders on numerical fluency (β =.71, *SE* =.24, *p* =.00). Head Start attenders scored approximately one-third of a SD higher than non-attenders on working memory (β =.44, *SE* =.24, *p* =.07), but this was marginally significant. They demonstrated no advantage on inhibitory control or cognitive flexibility.

Discussion

Our study was designed to re-examine questions about preschool impact fade-out in the context of a uniquely broad set of outcome assessments through third grade. In line with our hypotheses, we found that third grade effects of pre-k and Head Start attendance at age 4 were more consistently statistically significant and larger, on broader outcomes – including self-regulation – not typically measured in past preschool evaluations. These findings imply that prior evaluations may have missed some enduring benefits of public preschool attendance on key indicators of early school success.

Sustained Benefits on Third Grade Cognitive Skills

Past preschool evaluations have generally shown convergence between preschool attenders and non-attenders by the end of kindergarten or in first grade on typically measured

literacy outcomes like WJ LWID (Ansari et al., 2020; Author et al., *under review*; Lipsey et al., 2018; McCormick et al., 2021; Puma et al., 2012) and phonological awareness (Weiland et al., 2021). We too found convergence on these basic literacy skills. We suspect, as other scholars have recently argued, these constrained literacy skills are among the first skills taught and mastered in kindergarten by all children, regardless of preschool attendance.

By contrast, pre-k graduates in our study scored marginally higher than children who did not attend public preschool on unconstrained language skills like expressive vocabulary and passage comprehension; Head Start attenders scored marginally higher on passage comprehension. These results should be interpreted with caution since they do not reach conventional levels of significance. They are consistent, however, with a handful of recent studies, including our earlier research with this sample, showing sustained effects on unconstrained language skills like vocabulary and sentence structure (a precursor to passage comprehension) but convergence on WJ LWID in kindergarten (Ansari et al., 2020; McCormick et al., 2021; Author et al., *under review*) and first grade (Author et al., *under review*; Lipsey et al., 2018; Puma et al., 2012). Our findings are inconsistent, however, with convergence or even negative impacts on *both* constrained and unconstrained language skills at third grade as found in the Tennessee pre-k study (Lipsey et al., 2018).

With respect to math at third grade, both pre-k and Head Start attenders scored significantly higher than preschool non-attenders on numerical fluency; Head Start attenders also scored marginally higher on WJ AP. As mentioned, WJ AP is broad and thus unhelpful in informing questions about which math skills demonstrate convergence (or not). Numerical fluency, in contrast, is a specific math competency that improves with practice and doesn't have a ceiling, similar to language skills that are considered unconstrained. Our pattern of results

comports with findings from the few recent preschool evaluation studies including our own that, in kindergarten and first grade, assessed both WJ AP *and* more specific math skills such as numerical fluency and conceptual math understanding and found less convergence in the latter than the former (McCormick et al., 2021; Author et al., *under review*). By contrast, the Tennessee study's impacts on two specific math skills – calculation and quantitative concepts – were null or negative, respectively, at third grade; impacts on WJ AP were also null (Lipsey et al., 2018).

Vocabulary, reading comprehension, and numerical fluency are skills whose foundations may be more likely to be introduced, scaffolded, and promoted in preschool than at home with parents (Lyons et al., 2014; 2018; Snows & Matthews, 2016). Preschool attenders would thus be expected to enter kindergarten with more advanced skills than non-attenders, upon which instruction in kindergarten and early elementary school could build. Because these skills continue to grow over time and establish an increasingly strong foundation for more advanced learning, preschool non-attenders would be unlikely to catch up unless they are given more accelerated lessons in these skills upon entering school; little evidence suggests this is the case (Jenkins et al., 2018; Pearman et al., 2020), but more research is needed to understand which skills, for which children, are emphasized in post pre-k classrooms. By contrast, skills that are rapidly and fully acquired, and that are likely emphasized in kindergarten curricula such as LWID, basic counting, and shape recognition, are commonly mastered by all children in kindergarten, thus rapidly dissipating any advantage of preschool attendance.

Sustained Benefits on Third Grade Self-Regulatory Skills

We also documented significant benefits of preschool attendance on children's inhibitory control and working memory in third grade, particularly for TPS pre-k attenders. Head Start

attenders scored higher than non-attenders on working memory only and with marginal significance. The handful of prior studies that assessed children's self-regulation have found benefits of preschool attendance, but only through kindergarten (Ansari et al., 2021; Peisner-Feinberg et al., 2011; Weiland & Yoshikawa, 2013). Interestingly, in the current sample there were no impacts of either pre-k or Head Start on self-regulation in kindergarten or first grade (Author et al, *under review*), albeit using the NIH Toolbox rather than the pencil-tap (Smith-Donald et al., 2007) and HTKS (McClelland et al., 2007) tasks used in other studies. The NIH Toolbox may lack sufficient validity with children in the earliest grades (Weintraub et al., 2013), dampening our ability to detect preschool impacts prior to third grade. This arena of longer-term benefits is especially noteworthy in light of speculation that – untested thus far – preschool impacts on self-regulation serve as building blocks to middle and high school academic progress (Amadon et al., 2022; Durkin et al., 2021).

Limitations and Future Directions

Our results have several limitations. First, although we employ a quasi-experimental approach adopted by other recent preschool evaluation studies (e.g., Ansari et al., 2021; Hill et al., 2015; Weiland, et al., 2021), we cannot be certain that differential selection of children into preschool on unobserved variables is not confounding estimates of preschool benefits. The inclusion of a wide array of covariates and the elimination of most statistically significant differences after weighting provides some assurance that differential selection is unlikely to drive results. The extent to which our results replicate those reported by some prior studies that used the same measures also adds to the confidence that can be placed in our findings. Nevertheless, the differences between our findings and those of the Tennessee Voluntary Pre-k study in

particular call for additional research aimed at replication using the same range of outcomes, including self-regulation.

Additionally, the Tulsa context is unique and thus results may not be generalizable to other locales. First, the Tulsa program – like other contemporary pre-k programs demonstrating positive benefits (e.g., Boston) – is universal, meaning it is available to all families regardless of household income. Some evidence suggests that universal preschool programs produce stronger benefits than income-targeted programs that limit eligibility to families with low incomes (Cascio, 2019), like the program in Tennessee. Tulsa, for example, scores exceptionally high on preschool access, serving more than 70% of 4-year-olds across public program auspices. Public preschool in Tulsa is also higher on spending and quality than that in most other states. For instance, the National Institute of Early Education Research (NIEER) ranks Oklahoma 7th in the nation for total spending on public preschool, and as one of only five states (including TN) that meet 9/10 of NIEER's program quality benchmarks (Friedman-Krauss et al., 2020). CAP-Tulsa's Head Start and Tulsa Educare programs are also documented to be relatively high-quality (see Choi et al., 2016; Yazejian et al., 2015). Notably, beyond global quality data and indicators that are weakly associated with child outcomes (Phillips et al., 2022), more informative data regarding specific instructional practices in state pre-k classrooms and in the early elementary grades remain elusive. It is also necessary to replicate these results in other regions to test whether it is preschool in general, or something specific to Tulsa, that enabled longer-term gains in some key skills measured here.

Finally, outcomes were collected in the fall of 2021, as children returned from a year of remote learning due to COVID-19-induced school closures. Just as the Tulsa context for this study needs to be taken into account when considering the generalizability of our findings, so too

does its timing as the pandemic disrupted typical educational environments. It is well-documented that remote learning stymied academic growth among elementary school-aged children, especially those from low-income and minoritized backgrounds like the children in our sample (Engzell et al., 2021; Skar et al., 2021; Tulsa SEED Study Team, 2022). The implications of this massive educational disruption for sustained preschool impacts are unknown and could plausibly operate in either a positive or negative direction; fortunately, scholars are actively considering this question (Weiland & Morris, 2022). If remote learning minimized student growth, the impacts reported here may yet underestimate the true potential of public preschool, at least in Tulsa's universal program.

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Table 1

Sample descriptive statistics

	Mean/Percent	SD	N
Child race/ethnicity			694
Black	20%	-	
Hispanic/Latinx	54%	-	
Native American	6%		
White	11%	-	
Another race/ethnicity	1%		
Multiracial	8%	-	
Child is female	49%	-	694
Child is dual language learner	51%	-	694
Child age at start of preschool year	4.56	0.31	694
Child had an IEP in preschool	6%	-	637
Mother has more than high school education	35%	-	587
Mother is employed	64%	-	470
Mother was single at child's birth	50%	-	574
Mother's age at child's birth	26.32	5.96	568
Monthly income	1756.82	975.23	543
Household size	4.78	1.63	639

Table 2

Characteristics of preschool attenders and non-attenders, before and after weighting

	Preschool Non-Attenders (N=52)	Preschool Attenders - Unweighted				Preschool Attenders - Weighted			
		TPS pre-k (N=525)		Head Start (N=117)		TPS pre-k (N=525)		Head Start (N=117)	
	M/%	M/%	SMD	M/%	SMD	M/%	Std. Difference	M/%	SMD
Child race/ethnicity									
Black	8%	20%	-0.46	26%	-0.67	13%	-0.19	15%	-0.27
Hispanic/Latinx	37%	53%	-0.35	65%	-0.58	45%	-0.18	50%	-0.27
White	17%	11%	0.15	3%	0.36	10%	0.19	7%	0.28
Another race/ethnicity	39%	15%	0.47	6%	0.66	32%	0.13	29%	0.20
Child is female	39%	51%	-0.26	42%	-0.07	44%	-0.11	47%	-0.17
Child is dual language learner	46%	50%	-0.08	61%	-0.29	43%	0.07	49%	-0.06
Child age at start of preschool year	55.24	54.84	0.11	54.20	0.28	54.95	0.08	54.29	0.25
Mother has more than high school education	33%	37%	-0.09	31%	0.04	37%	-0.10	34%	-0.03
Mother is employed	51%	67%	-0.30	62%	-0.21	62%	-0.21	61%	-0.20
Mother was single at child's birth	51%	49%	0.05	52%	-0.01	51%	0.00	46%	0.11
Mother's age at child's birth	24.97	26.20	-0.21	27.25	-0.38	25.28	-0.05	27.34	-0.39
Household size	4.44	4.87	-0.33	4.51	-0.06	4.59	-0.11	4.59	-0.12
Monthly income	1729.24	1762.72	-0.04	1729.46	0.00	1765.20	-0.04	1741.20	-0.01

Note. Characteristics of preschool non-attenders (control group) do not change after weighting using the Average Treatment on the Control (ATC) approach. SMD=standardized mean difference. Covariates with SMDs post-weighting less than or equal to .25 are considered balanced.

Table 3

Results of IPT-weighted analyses predicting 3rd grade outcomes from preschool attendance

	English Literacy and Language											
	Letter-Word ID			Phonological Awareness			Expressive Vocabulary			Passage Comprehension		
Preschool Attender Group	*β*	*SE*	*p*	*β*	*SE*	*p*	*β*	*SE*	*p*	*β*	*SE*	*p*
TPS pre-k	0.19	0.17	0.27	0.15	0.17	0.40	0.33	0.16	0.05	0.30	0.16	0.07
Head Start	0.26	0.21	0.23	0.29	0.19	0.13	0.29	0.19	0.13	0.38	0.21	0.07
N			674			676			676			673

	Math						Self-regulation								
	Applied Problems			Numerical Fluency			Cognitive Flexibility			Inhibitory Control			Working Memory		
Preschool Attender Group	*β*	*SE*	*p*	*β*	*SE*	*p*	*β*	*SE*	*p*	*β*	*SE*	*p*	*β*	*SE*	*p*
TPS pre-k	0.33	0.20	0.11	0.46	0.18	0.01	0.26	0.16	0.10	0.37	0.17	0.03	0.32	0.15	0.04
Head Start	0.39	0.24	0.09	0.71	0.24	0.00	-0.20	0.23	0.38	0.24	0.21	0.26	0.44	0.24	0.07
N			673			686			686			687			684

Note. Betas are reported as effect sizes. The reference group in all models is preschool non-attenders. IPT weights are applied to all models and all models control for child race/ethnicity, child gender, child age at the start of the preschool year, maternal education, maternal employment, whether the mother was married at child's birth, mother's age at child's birth, dual language learner status, household size, and log of household income.