The Increase in Children’s Math Skill from an Experimental Increase in Parent Investment in Math Activities

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Abstract

Almost none of the research showing that greater parent engagement increases children’s cognitive skill exogenously increases parent engagement. In a randomized experiment we find that providing parents with information and materials relevant to engaging in math activities along with text messages to reduce present bias increased both parents’ engagement in math activities and children’s math skill. But a separate treatment that provided families with an electronic tablet and math apps that required no parent engagement increased math skill by at least as much.

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I. Introduction

All else equal a child’s skill development is a function of the amount of time a child is exposed to a skill and how much skill improvement is conveyed per unit of time—the efficiency of the exposure. For preschool-aged children, exposure to math concepts comes mainly from either preschool or parents’ engagement in math activities with the child. The importance of parental engagement to children’s skill development has long been recognized by economists (e.g., Becker, 1965; Hill & Stafford, 1974; Leibowitz, 1974 and 1977) and other social scientists (Coleman, 1966).1

Previous research that estimates the effect of parent engagement on child skill development is usually one of two kinds.2 First, many studies use survey or time use data and various statistical techniques to approximate causality rather than exogenously changing parents’ engagement. For example, Del Boca et al. (2012), Villena-Roldan and Rios-Aguilar (2012), Carneiro and Rodriguez (2010), and Hsin and Felfè (2014) use data from the Panel Study of Income Dynamics to estimate the relationship between parent time investment and child skills using various statistical techniques to approximate causal estimates. Bernal (2008) and Bernal and Keane (2011) use data from the National Longitudinal Survey of Youth. Del Bono et al. (2016) use the UK Millennium Cohort Study and Houtenville and Conway (2008) use data from the National Educational Longitudinal Study. Fiorini and Keane (2014) use children’s time use data from the Longitudinal Study of Australian Children. All these studies find positive effects of

1 Throughout this paper we use the term “parent” to refer to any caregiver for a child in our sample. In 2020 4% of caregivers are someone other than the child’s mother or father.

2 Note that there are large literatures on parent’s involvement in their children’s schools, on the general question of whether parents matter, and on parenting style; these are not addressed here.
parental engagement on children’s cognitive skill. The size of the effect is mixed because the measures of both parental engagement and child outcomes differs across studies. For example, Fiorini and Keane (2014) find that one extra hour a week spent in educational activities with parents rather than in other activities with parents increases child’s verbal ability by 0.034 standard deviations. Del Bono et al. find that a one standard deviation increase in a parent’s time in educational activities when the child is age 3 increases the child’s cognitive achievement at that age by 0.13 of a standard deviation. Villena-Rodan et al. find that a 1 percent increase in maternal time with a child increases the child’s score on a test of applied problem solving by between .015 and .198 standard deviations depending on the model. However, because the data in these studies is nonexperimental, questions remain about the size of the effect.

Second, several studies randomly assign parents to treatments intended to improve child outcomes by increasing parental engagement but do not measure both parent engagement and child outcomes (see, for example, Mayer et al., 2019; Sheridan et al., 2011; Rodriguez & Tamis-LaMonda, 2011; Aram & Biron, 2004; Landry et al., 2012; see also Van Voorhis et al., 2013 for a summary of interventions up to 2012). These studies cannot tell us how much child skill changes for a given exogenously induced change in parent engagement.

Only a handful of studies use random assignment to experimentally increase parent engagement and measure both the change in parent engagement and child outcomes. However, these studies usually have small samples so they may not be representative of any particular population, and they all estimate the effect of parent engagement on children’s literacy skill rather than math skill (e.g., see Barone et al., 2019 for summaries of research on shared book reading).
Four studies use randomization to identify the effect of an exogenous increase in parent engagement on child outcomes and measure both the change in parent engagement and the change in test scores form the treatment. The first is an evaluation of the Ready4K program (York & Loeb, 2018) in which parents of preschool children were randomly assigned to a control group or to a treatment in which they received several text messages each week for eight months that were intended to increase their literacy activities with their children. The messages provided tips for specific literacy-related tasks for parents to do with children as well as encouragement and framing to overcome present bias associated with child learning. The authors did not measure the amount of time that parents spent in literacy activities with their children, but parents in the experimental group were more likely than parents in the control group to report looking at pictures in a book, telling their child nursery rhymes, and showing their child different parts of a book. Children’s early literacy scores were greater for children in the treatment group compared to children in the control group, but the difference was not statistically significant at p=.05. However, because the sample of parents who reported their literacy activities was different from the sample of parents whose children had test score data and because there is no data on the amount of time that parents spent in literacy activities, it is not possible to estimate the effect of additional parent engagement on test scores from this study.

A second study estimates the effect of an intervention in which first-graders (N=587) were randomly assigned to receive an electronic tablet with an app that included short numerical story problems or to a control group. The app collected data on how much time the app was used. Unfortunately, the authors did not have data on how much time parents without the tablet and app engaged in math activities with their child, so they were only able to estimate differences in math skills for children of parents who used the app for different amounts of time, which was not
randomly induced, making it impossible to estimate the change in math score for exogenously induced changes in parents’ engagement in math activities.

In a study of how much shared book reading effects child literacy skill (Barone et al., 2020) preschools in France were randomly assigned to a control group or to a treatment group in which four-year-olds were give weekly information flyers to take home to their parents that included visuals and short passages on the importance of shared book reading. Parents also received a weekly phone call and text messages that summarized the information in the flyers, encouraging parents to read to their child, tips on effective reading, and encouraging parents to make reading a family affair. Teachers in the treatment schools were encouraged to provide book loan programs, and each child took one book home per week along with the information flyer. At baseline, 42% of parents reported reading to their child daily and at the end of the intervention 8% more parents in the treatment group compared to the control group reported reading daily. This increase in daily reading did not increase treatment children’s receptive vocabulary compared to control children on average. However, for parents with low education, the increase in parents’ reports of daily reading was 16% greater for parents in the treatment group (from a baseline of around 20%) and resulted in an increase in receptive vocabulary scores that was about 12% greater than children in the control group.³

The study closest to the MPACT evaluation is an evaluation of the Children and Parents Engaged in Reading project (Kalil et al., 2022), in which parents of preschool children were randomly assigned to a control group or to a group that received an electronic tablet with a

³ These are ballpark estimates of the effects of the shared reading intervention because the paper does not provide exact numbers. It also categorizes reading time in 4 categories with only one being daily reading, but it does not provide effect sizes for the other categories.
digital library of books, a group that received a tablet and digital library and 3–4 text messages per week reminding parents to read to their child using the digital library, a group that received the tablet and digital library and 3–4 messages per week that set a goal for how much parents should read to their child based on their previous amount of reading. The goal-setting group read the most minutes over the 45 weeks of the intervention and this same group had the greatest increase in literacy test scores. This study can only compare reading time for a parent who had the digital library, so it compares reading time across treatment groups. The goal-setting group read a little under two hours more than the reminder group (115 minutes more: 290 versus 405 minutes) over the 45 weeks and scored 8 percentile points more on an assessment of math skill (41 versus 49 percentile points) at the end of the intervention compared to the reminder group. Put another way, a 40% increase in reading time led to an 8 percentile point increase in literacy test scores.

II. Rationale for MPACT Treatments

The Math Parents and Children Together (MPACT) project uses a large-scale RCT with three treatments intended to increase the time that parents spend in math activities with their preschool-aged children and one treatment designed to increase children’s exposure to math concepts without necessarily increasing parent engagement.

The first three MPACT treatments address three main explanations for why parents do not engage their child in math activities: lack of information and materials, psychological barriers, and low expected return to engagement.

One MPACT treatment provides materials and information to help parents engage in math activities with their child. A large research literature documents the correlation between the
home learning environment and children’s skills (e.g., Kleemans et al., 2012; Niklas & Schneider, 2014; LeFevre et al., 2009, Marinova et al., 2021). An important aspect of the home learning environment is the availability of learning materials (Todd & Wolpin, 2007; Zadeh et al., 2010). In the literacy realm, survey data show that low-income families have fewer books than high-income families; as a result several large programs provide books to low-income families (e.g., Raising a Reader, Reach Out and Read). The home numeracy environment is often measured by the presence of counting and sorting objects, number flashcards, and board games (LeFevre et al., 2009; Ramani & Seigler, 2008; Benavides-Varela et al., 2017; Skwarchuk et al., 2014), along with parent attitudes and beliefs about child numeracy. However, we know of no large-scale programs to provide math materials such as puzzles and games to children.

Compared to information about how to improve children’s literacy skill, information from experts, including scholars, teachers, and other practitioners, about how to improve children’s math skill is somewhat abstract. Advice about improving literacy skill mainly includes reading to your child every day. In contrast, advice about improving children’s math skill urges parents to engage in “math talk,” read stories with math-related content, play board games, and do other activities that develop math skills among preschoolers. For example, a National Academy of Sciences report on math learning (National Research Council, 2009) advises that parents should “observe their children carefully, seeing what they do and encouraging and

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4 See, for example, https://www.huffpost.com/entry/book-charities-that-help-kids_n_6817484?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAJ27m9PWtWZtYpQUhtrH1NSodbzmsPPYTTbxjtcWs8ifCizyr9HymUnHW1lky2s3B8drAF8Y33gLnQUz0ZEYPFG1WcNmxuuJumCBUEIMn-4IozLFuwbUW9q0_hXS9CNfZ8MFUCTC4NZZVLJuq9IGCkozl1qCLOh4uiL7QGXqv1i.
extending their fledgling use of number symbols and processing; Say the number word list. For example, they can count small food items or the number of cups at the table; Ask children to tell them about their problem solving. For example, they can ask ‘What did you mean by that?’ or ‘Why did you do it that way?’; Engage in activities that involve playing with blocks, building things, and board games.” There is a vast difference in the cognitive load and the need for prior knowledge to execute the literacy advice (read a book everyday) compared to this math advice. In addition, the materials needed to help a child build literacy skill is clear—books—which it is much less clear what materials are needed to help a child build math skill.

Even if parents have information and materials for engaging in math activities with their children, psychological barriers may inhibit such engagement. A second MPACT treatment is designed to overcome one such psychological barrier—namely, procrastination that results from present bias. It is well known that future outcomes are underemphasized (discounted) relative to immediate outcomes, making it hard for people to give up things they enjoy today for things in the (undervalued) future. This results in problems of procrastination, which affect decision-making in many domains, such as savings and borrowing (e.g., Meier & Sprenger, 2010; Eckel et al., 2005), dieting, exercising, and smoking (e.g., Chabris et al., 2008), and investments in human capital (e.g., Sutter et al., 2013; Castillo et al., 2011). Disadvantaged parents face a host of stressors, such as income instability, childcare problems, or transportation issues, that place cognitive and emotional demands on their attention in the present and leave little energy for thinking about the future (Spears, 2011; Mani et al., 2013; Gennetian & Shafir, 2015) resulting in a greater possibility for the procrastination that results from present bias. For example, Pabilonia and Song (2013) found that even after controlling for parental differences in income, employment, and education, single mothers who are more present-oriented spend significantly
less time with their children overall and less time engaged with their young children in educational activities. Their children also have lower scores on reading comprehension tests. In our own research (Mayer et al., 2019), we find that a treatment to reduce present bias increased the amount of time that parents spent reading to their child using a digital library on an electronic tablet by 1 standard deviation and this treatment impact was much greater for parents who are more present-biased than for parents who are less present-biased.

Cunha et al. (2013) note that a central question of interest for public policy is how much early parental investments depend on parental expectations about how important their time investments are to their children’s skill development. Parents who believe that engaging in math activities with their child will help their child learn are more likely to spend time in math activities with their child than parents who believe that skills are innate and cannot be changed. Consequently, a third MPACT treatment is designed to promote a growth mindset. The concept of growth mindset is closely related to the idea of expected return on one’s time investment. Individuals with a growth mindset believe that skill can be developed through hard work, good strategies, and input from others. Individuals with a fixed mindset tend to achieve less than those with a growth mindset (Blackwell et al., 2007; Claro et al., 2016; Mangels et al., 2006). Most research on growth mindset has focused on people’s mindsets about their own intelligence. The few studies that have considered the role of parental mindset on child achievement have found that having parents with growth mindsets is associated with greater child achievement (Haimovitz & Dweck, 2016; Rowe & Leech, 2019; Andersen & Nielsen, 2016).

A fixed mindset is likely to result in a low expected return to spending time with one’s children and therefore it is likely to limit parents’ engagement with their children in learning activities. Attanasio, Boneva, and Rauh (2019) find that a measure of parents’ growth mindset is
positively and significantly correlated with parental beliefs about the returns to time investments. Parents who do not perceive children’s skills to be malleable in general also perceive the returns to investments to be lower. Attanasio, Boneva, and Rauh also find that the average perceived return to three additional hours of weekly time investments is 21% in their child’s adult earnings and an increase in the perceived return by 10 percentage points is associated with parents spending 46 more minutes every week on investment activities. While they find no difference in expected return by parental SES, other research does find a greater expected return is associated with greater family income (Agee & Crocker, 1996; Boneva & Rauh, 2018).

The fourth treatment MPACT provides an alternative to parent engagement for increasing exposure to math concepts in the form of an electronic tablet loaded with educational math applications for preschool-aged children. There are many reasons why an alternative to increasing parent engagement might produce more math learning among children. Changing parent behavior is difficult, and parent engagement in math activities may be inefficient at relaying math concepts. Parent engagement may be inefficient because, as noted above, the advice about how to help children learn math concepts is abstract compared to advice about improving children’s literacy skills, and the activities that parents can do to increase children’s math skill may be more demanding on both parents and children than the activities that they can do to increase literacy skills. Most children like having their parents read books to them but children may not always like playing games with rules, counting, and doing other math-related activities. In addition, a high proportion of low-income compared to higher-income parents are anxious about their own math abilities, and anxious about how to “teach” math (Maloney et al., 2014). Several studies show that parent anxiety about math reduces their engagement with their children in math activities (Casad et al., 2015; Gunderson et al., 2012; Maloney et al., 2015) and
that math anxiety is conveyed to their children. For example, Maloney et al. (2015) found that when parents of second grade children were more anxious about doing math, their children learned significantly less math over the school year and had more math anxiety by the end of the school year, but only if math-anxious parents report providing frequent help with math homework. These impediments to parent engagement in math may mean that digital materials that largely do not rely on parental engagement may be a more efficient way to increase a child’s exposure to math concepts.

In this paper, we describe the MPACT experiment and its sample of parents and children and the outcome measures before describing the main results and the results of sensitivity tests.

III. The MPACT Experiment

The 12-week MPACT evaluation was completed in three rounds, each with about a third of the sample. The total number of children in the sample was 1,278. Recruiting each family required many hours in which members of the research team first visited preschools in Chicago to explain MPACT and get them to participate. The research team members repeatedly visited preschools to recruit parents to participate, provide consent, and participate in surveys. A team of trained assessors also repeatedly visited preschools to assess children. The intensity of the recruitment process and the costs associated with giving families electronic tablets necessitated doing MPACT in rounds. The rounds began in fall of 2017, spring of 2018, and fall of 2018. All aspects of MPACT were approved by the University of Chicago Institutional Review Board. The MPACT field experiment is registered in the American Economic Association Registry for Randomized Controlled Trials, and the unique identifying number is AEARCTR-0002512. All documents used in MPACT were available in Spanish and English.
Treatments. Parents in the control group received an MPACT backpack with a story book in it at the beginning of the intervention. They received text messages reminding them when they would be surveyed and when their child would be assessed. Three of the treatments provided to parents an MKit with math materials and information. The MKit included a math activity booklet with twenty-two developmentally appropriate math activities for parents and children to do together, a game board, a number grid, game pieces, and a goal tracker. The goal tracker is a grid in which parents could keep track of the days on which they did math with their children. These materials were given to families in an MKit backpack.

The math activities in the booklet focused on five specific skill areas within the numeracy domain: number recognition, counting, comparing size and quantity, adding and subtracting, and patterns. An example of an activity in the booklet instructs the parent to ask the child to choose a number between 1 and 10 and then along with the child to make up a dance with that number. The Appendix includes an excerpt from the MKit. Each activity card provided instructions for how to do the activity and included tips for how to get the most out of the activity—for example, encouraging parents to use math words like more than and less than. The activity cards also provided suggestions for how to make the activity harder after the child mastered the skill. The booklet also included information on the importance of parents spending time in math activities with their child for the child’s future success.

The materials in the MKit were developed by our research team and informed by the recommendations in chapters 4 and 5 of a report by the National Academy of Sciences (Cross et al., 2009) and other professional recommendations parent engagement with their children to increase numeracy skills. The content of the MKit was extensively piloted to assure that parents understood the activities and were enthusiastic about doing them. At the follow-up survey of
parents (described below), 91% of parents said that they would recommend the MKit to a friend, and over 80% disagreed with the statement, “I did not need the MKit because I already know how to do math activities with my child.” When asked how much they would be willing to pay for the MKit, 73% said they were willing to pay $10 and over 40% said they were willing to pay $20.

Parents in the MKit treatment group received only the MKit. This treatment was intended to test whether providing information and materials to parents would improve children’s math skills. A second treatment group, the “present bias group,” received an MKit plus up to four text messages per week intended to overcome the procrastination associated with present bias. Although the wording of the messages differed each week, the primary content did not. One text message per week asked parents to set a goal for how many days they would do math activities with their child and encouraged them to write and track that goal in the goal tracker that was part of the MKit. An example of a goal message is, “It’s Goal Day. Set a goal for how many days this week you will do math activities with [CHILD_NAME]. Ask [him/her] to help you write it down on the MKit chart.” The messages did not direct parents to specific activities to engage in, nor did they suggest what the goal should be or how often the activity should occur. Setting a goal works as a soft commitment device to overcome present bias by increasing the psychological costs of not sticking to the goals (Bryan et al., 2010). Another text message suggested that parents share their goals with a friend or relative, which could also work as a soft commitment device by increasing the social cost of not achieving the goals.

A second kind of present bias message provided guidance about ways to overcome procrastination. An example of this kind of message is, “Did you know that people who make a plan are much more likely to achieve their goal? Make a plan for what you will do to reach your
math activity goal this week.” The final type of present bias message was a reminder that math engagement could occur at any time. An example of this kind of message is, “Remember to make time for your math goal even if you’re busy. Find numbers while you shop, cook, and visit family. Use your MKit chart to stay on track.”5 The present bias treatment was intended to increase children’s math skill over and above the MKit only treatment by overcoming a cognitive barrier to engaging in math activities.

A third treatment group, the “growth mindset group,” received an MKit plus up to four text messages per week that were intended to promote a growth mindset. An example of a growth mindset message is, “Math ability is not fixed. If you talk about math with [CHILD_NAME] every day, [his/her] math ability will grow.” Another example of a growth mindset message is, “How hard [CHILD_NAME] works is more important than getting the right answer. [CHILD_NAME] will want to do math activities if you praise [his/her] effort.” This treatment was intended to increase children’s math skill more than the MKit alone treatment by both providing materials and information and reducing the number of parents with a fixed mindset.

Parents in the fourth treatment group, the “math app group,” did not receive an MKit. Instead, they received an electronic tablet preloaded with eight apps intended to teach math skills to three-to-five-year-old children. This treatment was expected to increase the amount of time

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5 Parents in the MKit + present bias and MKit + growth mindset treatments in rounds 2 and 3 received booster messages for 12 weeks prior to their children’s third assessment (at 6 months after the evaluation ended) and for 12 weeks prior to their children’s fourth assessment (12 months after the evaluation ended). The booster messages included tips and encouragement texts designed to provide continuity of messaging. Booster messages had no effect on test scores for either treatment group.
that children spent in math activities but not necessarily parents’ engagement with their children in math activities. We reviewed dozens of math applications for three-to-five-year-old children. We selected applications that 1. were available in both Spanish and English; 2. worked on the tablets that we selected, with few problems; and 3. covered roughly the same math skills as the MKit. We piloted the applications to ensure that children could use the tablets and the apps, that they would encounter few technical issues, and that the applications were enjoyable. None of the math applications that we reviewed required parent engagement with the child to use the application. The choice of the math apps is described in the Appendix.

**Recruitment and Randomization.** Eligible parents for MPACT are those whose primary language was either English or Spanish, who had a child enrolled in one of 29 subsidized preschool programs in Chicago, who were between the ages of three and four years old enrolled in a participating preschool, and who were willing to sign a consent form. Parents also had to have a mobile phone and be willing to receive text messages. The preschool programs were located throughout the city and have racially and ethnically diverse populations. Language restrictions were due to limitations on the languages in which we could produce the MKit and find suitable electronic applications.

For each round, parents were recruited in one of two ways. In the eleven centers that allowed it, all eligible parents were automatically enrolled in MPACT but were given a chance to

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6 Tablets were set up so that parents could not access the internet from the tablets; therefore, no other apps or materials could be downloaded.

7 In other studies that we have done with a similar sample of Head Start parents, about 90% of parents reported having a working phone on which they could receive text messages (Kalil et al., 2019)
Eighteen preschools did not permit opt-out recruitment. In these centers, research assistants recruited parents in person by approaching them at drop-off and pick-up time to ask if they would be willing to participate. Participation rates were high at both opt-out (99%) and opt-in (71%) preschool centers.\textsuperscript{9}

We randomized in two stages. In the first stage, we randomly assigned classrooms across preschools to either a treated or untreated group. We assigned 15 classrooms (5 in each round) to the untreated group. All sample children in these classrooms were assigned to the control group. In the second stage, we randomly assigned students in the remaining sample classrooms to the control group or one of the treatment groups. We implemented this two-stage randomization so that we could detect peer effects, which we do not discuss in this paper.

\textbf{IV. Sample}

We use two samples for the analysis of MPACT. The parent sample includes parents who responded to the parent survey at both baseline and at the end of the intervention. The child sample includes children who were assessed at baseline, the end of the intervention, and six months after the end of the intervention. We initially recruited 1,459 children. Eleven children dropped out before randomization. Of the remaining 1,448 children, 93 were siblings of enrolled children. We dropped siblings, leaving only one child per parent. After randomization, 61 children dropped out. This included children in a preschool that closed after randomization, and children that left the preschool in which they were enrolled before we were able to collect any

\textsuperscript{8}Only the principal parent or guardian participated in MPACT.

\textsuperscript{9}The number of eligible parents was provided by preschool centers, and it is the number of parents who met the eligibility criteria for opt-out centers or the number of children in the classrooms for opt-in centers.
data on either parents or children. Ten children remained enrolled in the preschool but were chronically absent; we were not able to collect data on either parents or children. Another 6 children could not be assessed reliably because of either cognitive or behavioral problems. This left 1,278 children who were assessed at baseline.

The first column in Table 1 shows that children were randomized evenly across the MKit, growth mindset and present bias treatment groups. The control group is larger because all the children in the control group classrooms were assigned to the control group. We assigned fewer children (131) to the math app group because of the high cost of purchasing, distributing, and reclaiming tablets compared to the cost of the MKit, which families kept at the end of the treatment.

Column 2 in Table 1 shows that of the original 1,278 children who were randomized, 816 (63.8%) had data on both the first assessment and the assessment six months after the end of the treatment. This is the child sample with complete data used in most of the analyses below. The percent of children with complete data in the sample ranged from 59.5% for the math app group to 67.7% for the growth mindset group.

All parents of the 1,278 children who were initially assessed were asked to take the baseline parent survey. Of this sample, 987 parents participated in the baseline survey. These parents were fairly evenly distributed across the MKit, growth mindset, and present bias treatment groups with more parents in the control group and fewer in the math app group. Of the parents who participated in the baseline survey, 799 participated in both the baseline and follow-up survey. This represents 62.5% of the original sample of parents and 81.0% of the parents who took the baseline survey. The 799 parents who participated in both surveys are the parent sample used in the analyses below.
The first column in Table 2 shows baseline characteristics of all the children who were assessed at baseline. The second column shows these characteristics for all children with complete data at the end of the intervention and the last column shows the characteristics of children who had complete data at six months after the end of the intervention. More male than female children dropped out and slightly more children from opt-out centers dropped out. However, pairwise t-tests show that none of these differences from baseline to six months postintervention were statistically significant at p=.05.

The MPACT sample of 816 children who completed the baseline, postintervention, and 6-months postintervention assessments are younger than the national Head Start sample, primarily because we sampled younger children so that they would remain in preschool for the 6-month follow-up assessments. They are also more likely to be Hispanic and to speak Spanish at home. This is partly because of the demographics of Chicago and to the restriction on the MPACT sample to speak only English or Spanish (see Kopack Klein et al. 2021; Tarullo et al., 2017).

Table 3 shows characteristics of parents in the sample at baseline and at the end of the intervention. There were no statistically significant (p=.05) differences in these characteristics for either sample.

Figure 1 shows characteristics of the child sample and the parent sample by treatment group and a joint f-test test comparing children or parents in any treatment group with those in the control group for each characteristic. These characteristics are balanced across treatment groups and the control group with three exceptions. The treatment groups had more (p=.10) parents with some college than the control group, mainly because the math app group had more parents with some college. Significantly more parents in the treatment groups than in the control
group spoke English at home. The MKit group scored slightly higher (p=.05) at baseline than the control group, but the joint f-test shows no difference of baseline assessment scores between treatment groups and the control group. None of these sample characteristics differed significantly by round.

V. Outcome Measures

We assess the effect of each treatment on parents’ math engagement with their child and on children’s math skill. Here, we describe these outcome measures.

Intensity of parents’ math engagement. As with most other studies of parent’s time use, we do not have an objective measure of how much time parents spend in math activities with their child. We asked parents how many days over the previous week they helped their children count, recognize numbers, recognize shapes, and add or subtract. Responses were never (with a value of 0), 1 or 2 days (assigned a value of 1.5), 3 or 4 days (assigned a value of 3.5), and 5 or more days (assigned a value of 6). How many days parents engaged in math activities with their child depended on the activity. Just 2% of parents said they never helped their child count, but 40% said they never do addition and subtraction activities with their child. Parents help their child learn shapes and recognize numbers less than they help their child count but more than they do addition and subtraction with their child. Because exposure to math concepts is a function of both the amount of time and the type of activity, with advanced math activities producing greater math skill (Skwarchuk, 2009, Skwarchuk et al., 2014, Thompson et al., 2017), we create a score that weighs each kind of engagement by the inverse of the reported average frequency of the engagement at baseline meaning that time spent in counting activities gets less weight than time
in addition and subtraction. This assumes that parents who engage their child in more difficult tasks have a greater intensity of engagement. Math intensity is scored from 0 to 12 with 0 indicating no math engagement and 12 indicating the highest level of intensity of math engagement. The baseline intensity of math engagement has a mean of 6.34 and a standard deviation of 2.78. We also show the treatment effect on each kind of parent engagement.

**Child math skill.** The MPACT treatments were designed to develop skills related to number recognition, counting, comparing size and quantity, adding and subtracting, and patterns. To measure math skills, we use the Woodcock-Johnson IV Applied Problems subtest (WJ). This subtest focuses on numeracy skills, including counting, subitizing (i.e., ability to recognize the number of objects without counting them), adding and subtracting, sequencing, and matching numbers to their quantities. This contrasts with geometric and spatial competencies, which includes recognizing and naming shapes, construction of shapes, spatial imagery, and measurement. Children were assessed at the baseline, the end of the intervention, and six months after the end of the intervention.

The WJ percentile score indicates a child’s rank in math performance compared to a nationally norm-referenced group of children of the same age. A percentile score of 50 means that the child performed at the mean in the national pool of children at the same age. Figure 2

---

10 Research has demonstrated that socially desirable behaviors are overstated in surveys (e.g., Paulhus, 2002; Tourneau & Yan, 2007; Krumpal, 2013). Research comparing objective measures of parents’ time to parents’ reports of their time use show that parents on average overestimate the time they spend in educational activities with their children (Mayer et al., 2019). This research also shows that while the mean is likely to be too high, parents who report spending more time generally do spend more time in educational activities with their children, so the distribution is less distorted than the mean.
show shows the distribution of baseline WJ percentile scores for the 816 children with complete 
assessment data in the MPACT sample. At baseline the average child in MPACT scored at the 
24th percentile. This is consistent with other studies that show that children from low-income 
families score lower than children from high-income families, even before compulsory schooling 
begins (Fryer & Levitt, 2006, 2013; Katherine & Greg, 2016; Reardon & Bischoff, 2011; 
Waldfogel & Washbrook, 2011).

VI. Main Results

A. Treatment Effects on the Intensity of Math Engagement

To estimate the effect of the MPACT treatments on intensity of math engagement we use 
the following model:

\[ Y_p = \beta_0 + \beta_1 T_{1p} + \beta_2 T_{2p} + \beta_3 T_{3p} + \beta_4 T_{4p} + \alpha Y_{p0} + \gamma_c + \epsilon_{pc}, \]  
(1)

where \( Y_p \) is the intensity of parent engagement for parent \( p \) measured at the follow-up and 
\( Y_{p0} \) is the same outcome measured at baseline; \( T_{1p} \ldots T_{4p} \) are indicators for parent \( p \)’s 
assignment to the four MPACT treatment groups; \( \gamma_c \) is classroom fixed effects (because 
randomization was conducted within classrooms) and \( \epsilon_{pc} \) is an error term.\(^{11}\) For all estimates the 
control group is omitted so coefficients are the estimated difference from the control group. We 
also test the sensitivity of our estimates to including several controls, for various methods for 
imputing missing data, and for alternatives to estimating p-values.

\(^{11}\) We use classroom assignment at the time of randomization. One percent of children moved to a different 
classroom when the baseline assessment was administered, and 3% of children were in a different classroom at the 
time of the first follow-up assessment.
Table 4 shows that the tablet and present bias treatments increased the intensity of parents’ math engagement. Parents in the math app group had an increase in intensity of math engagement that was a third of a standard deviation greater than the increase for the control group. Parents in present bias treatment group has an increase in the intensity of math engagement that was 26% greater than the increase for the control group. These are large treatment effects compared to other interventions. For example, in the Head Start Impact Study the average treatment effect of being randomly assigned to Head Start was 17.9% of a standard deviation (p=<.01) on parents’ reports of engaging in math activities with their child after one year of being enrolled in Head Start (Padilla 2020; see also Bloom & Weiland 2015).

The next four columns in Table 4 show that the tablet treatment significantly increased all the components of the intensity of engagement scale. The present bias treatment increased all components except counting. The MKit treatment increased only the time parents reported spending counting with their child. The growth mindset treatments increased only the time that parents spend in adding and subtracting.

Because this study relies on parents’ self-reports of how much time they spend in math activities with their children, a potential concern is that parents exaggerate their engagement due to priming from the treatments. However, parents in the MKit and growth mindset groups did not report an increase in math engagement, so it would have to be the case that the tablet and present bias treatments provide greater priming than these other treatments. It is unlikely that the tablet treatment would provide greater priming than other treatments because this is the only treatment that did not provide any messaging to parents encouraging math engagement and the only treatment that did not require any parental engagement in math activities because all the math apps on the tablet were intended to be played by the child with no adult help.
B. Treatment Effects of MPACT on Children’s Math Skill

We use the same model as equation 1 to estimate the impact of the treatments on children’s WJ scores substituting the assessment score for the intensity of math engagement. Table 5 shows the estimated effect of the MPACT treatments on children’s WJ age-adjusted percentile scores. The estimates control for baseline WJ percentile score. Because the control group is the omitted group in the regression, the coefficient for each treatment is the average change in children’s WJ percentile scores for that treatment compared to the control group.

The first column in Table 5 shows the results at the end of the 12-week intervention and the second column shows the results six months after the treatments ended. There is no significant (p=.05) effect of any treatment on math scores, although children in the growth mindset group scored slightly lower than the control group (p=.06). After six months, the present bias treatment had a positive effect of 2.66 percentile points, and the math app group had a treatment effect of 2.80 percentile points. The standard deviation of the control group’s WJ score six months after the intervention ended was 19.29, so the effect size for the present bias group and the math app group was 13.8% and 14.5% of the control standard deviation respectively. However, neither estimate was significant at p=.05.

It is difficult to compare these effect sizes to the effect sizes found in other RCT evaluations of preschool mathematics programs. Most preschool math programs are curriculum based and multifaceted in that they are intended to change math, literacy and sometimes social emotional skill. Most also have components for both classroom and home math engagement. These include interventions such as Ready, Set, Leap (National Center for Education Research, 2008), which produced effect sizes close to zero (but not statistically significant) for three
measures of math skill. In an evaluation of Bright Beginnings (National Center for Education Research, 2008) the effect size for mathematics was between -.03 and .16 depending on the specific measure of math skill, but none were statistically significant. One of the best-known preschool interventions is the Building Blocks program, which includes both a preschool curriculum and an at-home component. However, it is impossible to estimate effect sizes from published data and the evaluation of Building Blocks suffers from other methodological problems (Sarama & Clements, 2006; Clements & Sarama, 2007). A comparison of MPACT to the few studies of math interventions with effect sizes shows that although the effect the the tablet and present bias treatments on children’s math skill are not statistically significant at p=.05, they are similar in size to the effect sizes of these much larger and more intense intervention.

C. Relationship between Parent Engagement and WJ scores

These results show that the MKit and growth mindset treatments did not increase parents’ reports of the intensity of their engagement in math activities with their children by a substantial or statistically significant amount, so it is no surprise that they also did not increase children’s WJ scores. The tablet and present bias treatments did increase parent engagement by a substantial amount (a third and a quarter of a standard deviation compared to the control group), and they increased test scores by a modest but not statistically significant amount.

The MKit treatment was intended to increase parent engagement by providing materials and information about how to engage children in math activities. To be effective, parents would have to use the MKit materials, but only 37% of the parents who were in this treatment group said that they did at least half of the MKit activities. Across the three treatment groups that
included an MKit, 19% of parents claimed that they did not receive a MKit. It is doubtful that so many parents who were supposed to receive an MKit did not receive one because the protocols for getting the right materials to families was strict and closely supervised. In contrast almost all parents (97.9%) who should have received a tablet reported that they did receive one. It is likely that parents who thought they did not get a MKit did get one but never used it. If parents did not use the materials that they received it is unlikely that this treatment would have any effect on any outcome.

The growth mindset treatment was intended to increase children’s WJ scores by increasing the extent to which parents believed that engaging their child in math activities would improve their child’s math skill. However, at baseline the median growth mindset value was 5 on a 6-point scale, and fewer than 25% of parents reported a growth mindset value of less than 3. This left little room for the treatment to increase the extent to growth mindset.

In addition, some evidence suggests that the MKit and growth mindset treatments reduced parents’ interest in doing math with their children. The MKit treatment increased the proportion of parents reporting that they “avoid doing math” with their children by 37% of the control group’s standard deviation (p=.05). The growth mindset treatment increased the number of parents who reported that “math is hard for my child” (p=.01) by 46% of the control group’s standard deviation.

Both the tablet and present bias treatments increased parents’ engagement in math activities and a modest and not statistically significant change in children’s WJ scores. Previous research uses different measures of both parental time inputs and child outcomes, so it is difficult to compare estimates of how much an increase in parental engagement affects child math skill across studies. Del Bono et al. (2016) find that a one standard deviation’s increase in parents’
time in educational activities with their child resulted in a .13 standard deviation increase in the child’s verbal skill. Villena-Roldan and Ríos-Aguilar (2012) find a considerably larger estimate. In their preferred model, a 1% increase in the weekly average maternal time engaged with a child results in an increase of .198 standard deviation in an applied problems assessment.

In MPACT the effect of the tablet treatment implies that an increase of .90 in the intensity of parents’ math engagement leads to an additional 2.80 percentile points in the WJ percentile scores. The increase in math engagement is about a third of the control group standard deviation and the effect size of the tablet treatment on WJ scores is about 15% of the control group standard deviation. This effect size is in line with previous research and perhaps even larger than the effect found in previous research, especially because the MPACT sample is disadvantaged. Previous research shows a greater improvement in children’s cognitive skill from engagement with parents who have more education, are in a two-parent family, and who are white (Villena-Roldan & Ríos-Aguilar, 2012; Del Bono et al., 2016; Hsin, 2008). While the size of the increase in parental engagement on children’s test scores is similar to what is found in other studies, the MPACT sample is smaller than in the studies using survey or time use data, so the MPACT estimates are not statistically significant at p=.05.

D. Heterogeneity

We expected some treatments to have a greater effect on parents with specific characteristics. We expected the growth mindset treatment to have a greater effect on parents who at baseline had a more fixed mindset. We expected all treatments to have a greater benefit for children whose parents had the least intensity of math engagement at baseline because they had the greatest opportunity for improvement. To narrow the gap between advantaged and
disadvantaged children, the treatments would have to have a greater benefit for disadvantaged than advantaged children, so we also consider whether the treatments had a greater benefit for children whose parents have less education and whether they had a greater benefit for children who had low baseline WJ assessment scores.

We use the following model to estimate heterogeneity effects:

$$Y_{ic} = \beta_0 + \beta_1 T_{1ic} + \beta_2 T_{2ic} + \beta_3 T_{3ic} + \beta_4 T_{4ic} + \phi Z_{ic} + \alpha Y_{ic0} + \gamma_c +$$

$$+ \theta_1 T_{1ic} \times Z_{ic} + \theta_2 T_{2ic} \times Z_{ic} + \theta_3 T_{3ic} \times Z_{ic} + \theta_4 T_{4ic} \times Z_{ic} + \epsilon_{ic},$$

where $Y$ is child’s WJ score at the end of the intervention and $T$ is a treatment group. This model controls parents’ baseline characteristic and omits the control group as in prior analyses, so the coefficient for each treatment can be interpreted as the change in the score from the baseline compared to the control group. We detect no significant (at even $p=.10$) interactions for any treatment with children’s baseline WJ scores, parents’ baseline intensity of engagement, or parents’ baseline growth mindset. We also detect no significant interactions with the language spoken at home or parent’s education level.

**E. Sensitivity tests for missing values and controls**

It is not surprising that collecting data over 18 weeks in a mobile, low-income sample results in a considerable amount of missing data. We have presented results using only observed data. We tested the sensitivity of our results to several ways of imputing missing data, including multiple imputation (Rubin, 1996, 2004; Schafer, 1999), assigning the group mean to the missing cases, and inverse probability weighting (Horvitz & Thompson, 1952; Robins et al., 1994). We tested several different ways of imputing data because each makes somewhat different assumptions about the source of missing data.
Although imputing data by any of these methods increases sample size, none changes the substantive conclusion that only the tablet and present bias treatments increase the intensity of parents’ engagement with their children in math activities and none of the treatments increase children’s WJ score by a significant amount (p=.05).

We also tested the sensitivity of our results to the addition of control variables. We estimated models that included the two factors that were not balanced across the treatment and control groups—namely, having English spoken at home and the parent having some college. These controls had negligible impacts on our estimated treatment effects and did not change significance levels, so there were no substantive differences in the results from including these controls.

We also use randomized inference as an alternative way to estimate significance levels (Athey & Imbens, 2016). This method of estimating p-values may be superior to parametric estimates when the sample has been randomized into treatment groups. To do this we created a set of counterfactual treatment effects by statistically altering treatment assignment across the sample. We then rank these treatment effects to see where our actual estimate lies within the distribution of possible effects. The p-value is the percentile rank of our estimate compared to counterfactual estimates. The percentile rank tells us how unusual our estimated treatment effect is. For example, if our estimated treatment effect is 10 and the distribution of random assignments shows that in the absence of any treatment this treatment effect would occur only 2% of the time then the p-value would be 0.02. However, the p-value estimates from randomized inference were very similar to the p-values from parametric estimates, and in no case did they change the conclusion about significance levels.
VII. Conclusions

In this paper, we estimated the effect of the four treatments that were part of the MPACT intervention on preschool children’s math skill. Three of these treatments were intended to increase parents’ engagement in math activities with their children as a way to increase children’s math skill. The fourth treatment, the tablet treatment, was intended to increase children’s exposure to math concepts through digital apps that did not require parental engagement. Only the tablet treatment and the present bias treatment increased the intensity of parent’s engagement in math activities with their child and no treatment increased children’s math skill by a statistically significant amount, even though the size of the effects for the tablet and present bias treatments were in line with previous research. These results confirm what many other studies have found: information and materials alone are unlikely to change parent behavior because many parents who received information and materials did not use them. Our recent research with a similar sample shows that low-income parents experiencing stress or financial scarcity do not attend to information that they receive (Kalil & Mayer, 2022), so it may not be surprising that in this low income sample many parents did not attend to information when they received it.

These results also indicate that even in a low-income sample few parents have a fixed mindset, so interventions that focus on fostering a growth mindset are unlikely to alter many parents’ attitude about the importance of exposing children to math concepts, which also means that such interventions are unlikely to change parent behavior or child skill.

The MPACT results also indicate that a potential barrier for parents to use math related materials when they are available is present bias. When parents were reminded to use the MKit and urged to set a goal for doing math activities, they reported doing more of these activities.
This is consistent with our previous research (Mayer et al., 2019) showing that an intervention to reduce the procrastination associated with present bias increased the amount of time that parents read to their children using an electronic app and that the effects were the greatest for parents who at baseline were the most present biased.

Our results and the estimates in other research shows that it would take a very large increase in parental engagement in math activities to raise children’s math skills appreciably. This suggests that parent time in math activities may be relatively inefficient. If true, equalizing children’s math skill at the beginning of kindergarten may require an alternative to increasing parent engagement during the preschool years. Digital apps may be one such alternative. We find that providing children with digital apps produced the largest change in both the intensity of math engagement and test scores and at a lower cost than many other interventions to increase math skill. This points to the need for more research on how digital materials and other alternatives to parent engagement might be used to narrow the gap in math skill at the beginning of kindergarten.

References


https://www.mdrc.org/sites/default/files/quantifying_variation_in_head_start.pdf


https://doi.org/10.3389/fpsyg.2015.01597


Table 1. Sample size by treatment group for parent and child sample with complete data

<table>
<thead>
<tr>
<th></th>
<th>Randomized child sample</th>
<th>Child sample with complete data</th>
<th>Randomized parent sample</th>
<th>Parent sample with complete data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>366</td>
<td>231</td>
<td>274</td>
<td>218</td>
</tr>
<tr>
<td>Math App</td>
<td>131</td>
<td>78</td>
<td>111</td>
<td>95</td>
</tr>
<tr>
<td>MKit</td>
<td>258</td>
<td>165</td>
<td>189</td>
<td>152</td>
</tr>
<tr>
<td>Growth mindset</td>
<td>260</td>
<td>176</td>
<td>205</td>
<td>162</td>
</tr>
<tr>
<td>Present bias</td>
<td>263</td>
<td>166</td>
<td>208</td>
<td>172</td>
</tr>
<tr>
<td>Total</td>
<td>1278</td>
<td>816</td>
<td>987</td>
<td>799</td>
</tr>
</tbody>
</table>
Table 2. Comparison of baseline characteristics for the child samples by time since the end of the MPACT intervention

<table>
<thead>
<tr>
<th></th>
<th>Complete data at baseline</th>
<th>Complete data at end of the intervention</th>
<th>Complete data 6 months post intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of children</td>
<td>1,278</td>
<td>1,168</td>
<td>816</td>
</tr>
<tr>
<td>Proportion from opt-in centers</td>
<td>0.574</td>
<td>0.573</td>
<td>0.605</td>
</tr>
<tr>
<td>Proportion who are female</td>
<td>0.519</td>
<td>0.527</td>
<td>0.534</td>
</tr>
<tr>
<td>Mean age in months</td>
<td>46.978</td>
<td>46.955</td>
<td>46.587</td>
</tr>
<tr>
<td>WJ percentile scores</td>
<td>23.9</td>
<td>24.2</td>
<td>24.4</td>
</tr>
</tbody>
</table>

Note: Pairwise t-tests show that there are no significant differences of baseline characteristics by time (p=.05).
### Table 3. Comparison of baseline characteristics for the parent samples by time since the end of the MPACT intervention

<table>
<thead>
<tr>
<th></th>
<th>Complete data at baseline</th>
<th>Complete data at end of the intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number who took the survey</td>
<td>987</td>
<td>799</td>
</tr>
<tr>
<td>Proportion with less than a high school credential</td>
<td>0.257</td>
<td>0.259</td>
</tr>
<tr>
<td>Proportion with a high school credential</td>
<td>0.277</td>
<td>0.269</td>
</tr>
<tr>
<td>Proportion with some college degree</td>
<td>0.333</td>
<td>0.338</td>
</tr>
<tr>
<td>Proportion with college or higher degree</td>
<td>0.077</td>
<td>0.080</td>
</tr>
<tr>
<td>Proportion who speak Spanish at home</td>
<td>0.548</td>
<td>0.568</td>
</tr>
<tr>
<td>Mean household income in previous year</td>
<td>$19,431</td>
<td>$19,245</td>
</tr>
</tbody>
</table>

Note: Pairwise t-tests show that there are no significant differences of baseline characteristics by time (p=.05).
Table 4. Estimated effect of MPACT treatments on intensity of parent-child math engagement and specific forms of engagement

<table>
<thead>
<tr>
<th></th>
<th>Intensity of parent math engagement</th>
<th>Parent reports of number days per week they did each activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Counting</td>
</tr>
<tr>
<td>Math app</td>
<td>0.90***</td>
<td>0.54***</td>
</tr>
<tr>
<td></td>
<td>(0.33)</td>
<td>(0.21)</td>
</tr>
<tr>
<td>MKit</td>
<td>0.21</td>
<td>0.31*</td>
</tr>
<tr>
<td></td>
<td>(0.31)</td>
<td>(0.19)</td>
</tr>
<tr>
<td>Growth mindset</td>
<td>0.31</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>(0.29)</td>
<td>(0.18)</td>
</tr>
<tr>
<td>Present bias</td>
<td>0.70***</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>(0.29)</td>
<td>(0.18)</td>
</tr>
<tr>
<td>Baseline measure</td>
<td>0.48***</td>
<td>0.43***</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Constant</td>
<td>3.36***</td>
<td>2.08***</td>
</tr>
<tr>
<td></td>
<td>(0.30)</td>
<td>(0.18)</td>
</tr>
<tr>
<td>Control mean</td>
<td>6.18</td>
<td>3.71</td>
</tr>
<tr>
<td>Control SD</td>
<td>2.69</td>
<td>1.65</td>
</tr>
<tr>
<td>N</td>
<td>741.00</td>
<td>791.00</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.47</td>
<td>0.40</td>
</tr>
</tbody>
</table>

Notes: The omitted group is the control group. Regressions include the baseline measure of the outcome and classroom fixed effects. Standard errors are in parentheses. *p<0.1, **p<0.05, ***p<0.01
Table 5. Estimated effect of MPACT treatments on children’s WJ percentile score

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>End of intervention</td>
<td>6 months after the end of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>intervention</td>
</tr>
<tr>
<td>Math app</td>
<td>-0.91</td>
<td>2.80</td>
</tr>
<tr>
<td></td>
<td>(2.72)</td>
<td>(2.26)</td>
</tr>
<tr>
<td>MKit</td>
<td>-3.23</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>(2.13)</td>
<td>(1.98)</td>
</tr>
<tr>
<td>Growth mindset</td>
<td>-3.53*</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td>(2.02)</td>
<td>(1.89)</td>
</tr>
<tr>
<td>Present bias</td>
<td>1.20</td>
<td>2.66</td>
</tr>
<tr>
<td></td>
<td>(2.12)</td>
<td>(1.86)</td>
</tr>
<tr>
<td>WJ percentile rank</td>
<td>0.75***</td>
<td>0.51***</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Constant</td>
<td>10.50***</td>
<td>9.02***</td>
</tr>
<tr>
<td></td>
<td>(1.55)</td>
<td>(1.44)</td>
</tr>
<tr>
<td>Control mean</td>
<td>27.33</td>
<td>21.51</td>
</tr>
<tr>
<td>Control SD</td>
<td>23.90</td>
<td>19.29</td>
</tr>
<tr>
<td>N</td>
<td>816.00</td>
<td>816.00</td>
</tr>
<tr>
<td>R²</td>
<td>0.59</td>
<td>0.51</td>
</tr>
</tbody>
</table>

Notes: The control group is omitted. Regressions include baseline measures of the outcome and classroom fixed effects. Standard errors are reported in parentheses. *p<0.1, **p<0.05, ***p<0.01
Figure 1. Comparison of baseline characteristics of children and parents by treatment group

Notes: Each row is a separate regression in which the dependent variable is indicated in the first column and the explanatory variables are treatment groups (with the control group as the omitted category). The dots in the graph are point estimates and the horizontal lines depict their 95% confidence intervals. P-values from joint significance test of treatment groups are reported in the last column.
Figure 2. Distribution of WJ percentile scores for children participating in MPACT

Notes: Sample is for 816 children who participated in all 3 assessments.
Appendix: MPACT materials

MKit. The content of the MKit was developed by BIP Lab staff and it was illustrated by a professional illustrator to be visually pleasing to both parents and children. The MKit include a booklet that described activities that parents and children could do together to promote math learning. Each page included a section called, “What Your Child Should Learn” that described the skill that each activity was intended to foster. Each activity page also included a way to make the activity more difficult as children mastered each skill and a section titled, “Math Is Everywhere” that described how the skill developed in that activity could be reinforced in everyday activities such as visit to the grocery store. The activities were intended to require almost no materials that could not be found in almost every house, the MKit also in included a game board with game pieces and some of the activities described ways to use the game board. The MKit also included a Number Helper and some of the activities relied on this. The MKit also included a page with a “Goal Kit” that parents could use to keep track of their goals for going math with their children. The MKit+present bias treatment is the only treatment in which parents were asked to set a goal.

Figures A1 to A3 show some of the components of the MKit. As the first picture shows, all these components were given to each family in a bag with MPACT written on it.
Figure A1.1 A View of the MKit as it was given to parents.

Figure A1.2 An example of a page from the MKit

Count the dots

What your child will learn:
Counting objects, comparison, adding.

**STEP 1**
Ask your child to look at these dot drawings on the MKit card and count how many dots it takes to make each object.

Begin counting with the dot that is black. Be sure to have your child touch each dot while counting. Begin with the object with the fewest dots and continue to the objects with more dots.

**STEP 2**
Ask your child, “Which object has the most dots? Which has the fewest dots?”

Caterpillar has ___ dots.   Fish has ___ dots.
Figure A1.3 The game board form the MKit

Figure A1.4 The MKit Number Helper
**Math Apps.** To select the applications used in the tablet treatment, we began by reviewing educational math applications for children ages 3 to 5. We restricted our search to iPad compatible iOS apps available in both English and Spanish and focused on skills comparable to those highlighted in the MKit, namely numeracy-related skills. We also tried to select apps that balanced high-quality math activities with sufficient animations and sounds to reward the child for progress but not distract from learning. We screened apps to be sure they worked with no technical difficulties on the iPads and were user-friendly for first-time tablet users. We reviewed 50 apps that met these requirements produced in the United States, Australia, England, Spain, and Mexico. From these we identified six apps for use in a pilot study. The apps used in our pilot study were:

Table A2.1: iPad applications for the pilot study

<table>
<thead>
<tr>
<th>Pilot Applications for the MPACT tablet treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>123 Go</td>
</tr>
<tr>
<td>Lipa Frog</td>
</tr>
<tr>
<td>Lola's Math Train</td>
</tr>
<tr>
<td>Drive About Number Neighborhood</td>
</tr>
<tr>
<td>Monkey Preschool Lunchbox</td>
</tr>
<tr>
<td>Learning Patterns</td>
</tr>
</tbody>
</table>

During exit interviews after the pilot, we found that parents and children were able to easily use the iPad apps, parents felt apps were the appropriate difficulty level for their child and that the applications provided enough variety to capture their child’s interest even for a longer time period.

After the pilot, we omitted two of the apps included in the pilot (Money Preschool Lunchbox and Learning Patterns) because they focused on skills not included in the MKit, and we added 3 apps (Arithmetics Pro, Animal Math and KidsMath) because they more closely
focused on numeracy. Consequently, the tablet treatment included the 7 math apps shown in Table A2.2.

Table A2.2 Applications used in the tablet treatment

<table>
<thead>
<tr>
<th>Full Study Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>123 Go</td>
</tr>
<tr>
<td>Lipa Frog</td>
</tr>
<tr>
<td>Lola's Math Train</td>
</tr>
<tr>
<td>Drive About Number</td>
</tr>
<tr>
<td>Neighborhood</td>
</tr>
<tr>
<td>Arithmetics Pro</td>
</tr>
<tr>
<td>Animal Math</td>
</tr>
<tr>
<td>KidsMath</td>
</tr>
</tbody>
</table>