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Extending an Effective Classroom-Based Math Board Game Intervention to Preschoolers' Homes

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Introduction

The math skills that children display in kindergarten are important predictors of their subsequent progress in math and other academic domains.[1-4] Unfortunately, far too many children in the US start kindergarten lacking the math skills needed for academic success.[5] For example, in 2015 only 42% of children in Maryland entered kindergarten with adequate foundational math skills.[6] Children from low-income backgrounds, on average, score at least one half standard deviation below children from more affluent backgrounds in kindergarten and early elementary school.[2,5,7-10] In fact, preschool children from low-income backgrounds may be as much as one year behind their middle-income peers in math.[11] These early income-related gaps in math skills remain stable or increase as children proceed through school.[5] Thus, it is critical to improve children's math skills as early as possible, even before the start of formal schooling.

This paper presents two studies of the effects of a home-based math intervention with Head Start families. We focus on the home because young children are exposed at home to opportunities to acquire math skills even before formal schooling.[12-16] We focus on low-income families because, as noted above, these children often begin school with more limited math skills than their higher-income peers.[2,5,11] An effective home math intervention could have important implications for closing group-based gaps in young children's current and future math skills. In what follows, we briefly review children's early math skills. We then discuss children's math home learning environments and attempts to improve their early math skills.

Children's Early Math Skills

Even before the start of formal schooling, children begin to develop number sense,[5,17,18] a competency which is positively related to subsequent math development.[5,19] Number sense includes skills such as counting, number knowledge, number transformation, estimation, and knowledge of number patterns.[20] Magnitude knowledge, the ability to distinguish number size, is a key component of many of these skills.[21,22] Magnitude knowledge includes ordinal judgment, magnitude comparison, counting, and number identification.[22,23] Low-income children, on average, score significantly lower than their middle-income peers on measures of number sense in kindergarten.[2,20] Thus, it is important to look for ways to improve these early math skills, particularly in low-income children.[16]

Children's Math Home Learning Environment

Parents expose their children to many math-related activities from a young age by using number talk, involving their children in everyday math activities, playing games that involve math with their children, serving as role models of math engagement, and formally teaching math.[13,15,24-26] Such activities are positively associated with children's math development. For example, Sonnenschein et al[27] found that the extent to which parents served as role models of math engagement was positively associated with the frequency of their preschool children's math engagement and math development. Susperreguy and Davis-Kean[28] found that the amount of math talk parents engaged in with their preschool children was positively associated with their math skills a year later (see also Skwarchuk et al[26]). Although the math home learning environment is positively associated with children's math skills and parents highly rate the importance of their children engaging in math activities at home and assisting their children with such activities,[27,29] many parents report not knowing what to do to facilitate their children's math development.[30] This suggests that home-based math interventions might be an important means of improving young children's math skills through informing parents' practices.

Low-income children engage in math activities at home less frequently than middle-income children.[2,11,15,31,32] Kalil et al[33] compared several nationally representative data sets and found that the gap in the frequency of math-related activities engaged in at home between low- and middle-income families has increased over the past 25 years. Sonnenschein et al[27] found that low-income preschool children engaged in math activities, on average, once to several times a week. In contrast, middle-income children did so several times a week to almost every day.[34] One math activity which may be of particular importance is playing math-related games. Ramani and Siegler[35] found that low-income preschoolers had less experience than their middle-income peers playing such games at home. Their limited experience is of particular concern because, as discussed in the next section, board games may be an important means of acquiring certain foundational math skills. The income-related differences with which children, on average, engage in math activities at home may be associated with income-related math achievement gaps.[14-16,35]

Improving Children's Math Skills

Most of the interventions aimed at improving children's math skills have been school-based and have involved a substantial revision of the math curriculum, many intervention sessions, extensive involvement of the researchers (e.g., Xu & LeFevre[22]; Dyson et al[23]), and some form of electronic medium.[36] Some of the interventions have included a parent component that was coordinated with what was occurring in the classroom (e.g., Starkey et al[32]; Sheldon & Epstein[37]). Not surprisingly perhaps, the

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effectiveness of the programs varied with the intensity of the intervention.[38] For example, programs that included more or longer training sessions had larger effects.

Currently, very few home-based math interventions are available to young children and parents. The interventions that have been created require, for the most part, many training sessions (e.g., Starkey & Klein[39]; Van Tuijl et al[40]; cf. Niklas et al[24]), and involve providing families with electronic tools.[41] However, the electronic tools are typically taken away at the end of the study. Equally important, such interventions are costly and may not be feasible when funds are more limited. Given the importance of improving low-income children's math skills before the start of kindergarten, it is critical to develop effective and inexpensive tools that parents can and will use at home to facilitate their young children's math skills. However, as the results of the two studies in this paper will show, it can be very challenging to design such an intervention (see also Fishel and Ramirez[42]).

We sought to fill a gap in the existing literature by exploring the effectiveness of a classroom-based intervention that we adapted for use by parents of low-income preschool children. We modeled the current set of studies after the successful math board game intervention implemented by Ramani and Siegler with low- and middle-income preschool children in their schools.[31,35,43-45] Ramani and Siegler[35] argued that playing board games, particularly linear ones that include numbers, may be a very effective way for children to develop the critical linear numerical representational skills necessary for math development (see also Siegler and Ramani[45]). The children in those studies played a board game developed by the experimenters. Children had to move a game piece the number of spaces indicated on a spinner. Children in one condition (number game intervention) saw the numbers 1 to 10 on each space on the board game. Children in the other condition (color control) played the same game without the numbers or the counting component. The game was played in small groups with the experimenter at school. There was about 1 hour of game playing time per child, spread over 2 weeks. Several of the findings were noteworthy. One, based on responses to a questionnaire given to the children, low-income children had significantly less experience playing board games at home than middle-income children. Two, children in the number game intervention condition improved their math skills more than those in the color game control condition. Three, the gap between low-income and middle-income children's magnitude knowledge was closed for those children in the number game intervention. Ramani and Siegler[43] suggested that sending home games like *Chutes and Ladders* may be an effective home-based intervention because it is similar to the game they used in their number intervention condition.

Parents' beliefs are not typically considered in interventions. However, parents' beliefs about their role in their children's development guide the activities they make available to their children.[27,43,46,47] Given research on parents' beliefs and its relation to the home learning environment,[27,47] parents' beliefs also may be associated with whether they comply with an intervention. Having time to engage in the intervention is also an important issue. For example, one of the components of the often-cited Hoover-Dempsey model of why parents become involved in their children's education is whether they have the time to do so.[48] More generally, having an understanding of children's math home learning environment seems an important issue when implementing math interventions. If the activities suggested by intervention programs are not a natural part of a family's home environment, it may be much more difficult to get parents to "buy in" and participate. Thus, understanding families' beliefs and practices is essential for successful home-based interventions.

The Present Study

Children's early number skills are a critical component of their subsequent math development.[1,21] However, many low-income children enter kindergarten significantly behind their middle-income peers in such knowledge. Developing effective and feasible home-based math interventions is one means of closing the gap in math skills. This paper discusses the difficulties of getting a simple math intervention, effectively used in the classroom with low-income preschool children, to succeed in the home.

The two studies in this paper utilized a well-known, commercially available children's board game, *Chutes and Ladders*, to improve children's math skills. The studies addressed three research questions. One, can a successful classroom-based math board game intervention be effectively implemented at home? That is, will parents of Head Start children adhere to a specific count-on procedure when playing a number board game with their children? Two, will the intervention improve Head Start children's early math skills? Three, are parents' beliefs related to whether they comply with the math intervention; and do parents' beliefs about children's math activities and children's home math engagement relate to children's math skills?

Study 1 was a home-based adaptation of Ramani and Siegler's[35] successful classroom intervention. We compared the effectiveness of training parents to play *Chutes and Ladders* with the effectiveness of playing *Candy Land*, another popular board game. *Chutes and Ladders* has numbers; *Candy Land* (comparable to Ramani and Siegler's[35] color control game) does not. Parents in the *Chutes and Ladders* count-on procedure condition were taught to count numbers on the game spaces in keeping with the count-on procedure used by Ramani and Siegler.[35] That is, they counted numbers written on the game-board spaces instead of just the number spun on the spinner. Although children showed improvement from pre- to post-intervention in their early math skills, the intervention did not have a significant effect. Study 2 utilized information from focus groups with parents to modify the intervention conditions.

Study 1

Method

Participants. Eighty-four children (43% girls; 100% African American/Black) and their parents participated in Study 1. Note that the majority of the children in Baltimore City Head Start centers, particularly the ones from which we recruited for Studies 1 and 2, are African American/Black. Children's mean age at pre-intervention was 4.00 years (*SD* = 0.54). Children attended 1 of 4 Head Start centers in Baltimore, Maryland. Families were recruited through invitational letters sent home with the children.

Forty percent (*n* = 34*)* of the parents participated in post-intervention interviews about the game and their beliefs about their children's math learning and activities. Of those parents, 77% (*n* = 26) were mothers, 15% (*n* = 5) fathers, and 9% (*n* = 3) other relations of the child. Three percent (*n* = 1) had a bachelor's degree, 50% (*n* = 17) had completed some college/vocational/technical school, 29% (*n* = 10) had graduated high school, and 18% (*n* = 6) had less than a high school education.

Measures.

Early math skills. Pre- and post-intervention tests of early math skills were adapted from measures used by Ramani and Siegler.[35]

Counting. Children were told, "Please count as high as you can for me." Children's scores were the highest number they counted before making a mistake.

Number line estimation. Children were shown a blank number line with 0 at the beginning and 10 at the end of the line. A target number was positioned a couple inches above the number line. Children were asked to point where on the number line the target number belonged. Children were shown each number from 1 to 9 twice in random order. We used Ramani and Siegler's[35] coding scheme for scoring responses. Percentage of absolute error was calculated for each response by measuring the distance between the target number's actual position on the number line and where the child pointed. This distance was divided by 10 (number of intervals on the number line) and multiplied by 100. For example, if the target number was 6 and a child pointed to the position for 1 on the number line, percentage of absolute error would be $\left(\left|\frac{1\text{-}6}{10}\right| \times 100\right)$ = 50%. Children's scores were the average percent error across all items.

Magnitude comparison. Children were shown a card with 2 single digits and told, "Aaron/Alicia (matched to child's gender) had 5 cookies, and D'Andre/Donna had 1 cookie. Which is more: 5 cookies or 1 cookie?" Two examples were given to ensure children understood the task directions. Children's scores were the number of correct responses out of the 18 non-example items.

Numeral identification. Children were shown a number from 1 to 10 on a card and asked "What number is this?" Children's scores were the number of correctly identified numerals out of 10 items.

Math home learning environment. The questionnaire used to assess the children's math home learning environment was adapted from one used by Sonnenschein et al.[27] The adapted version contained open-ended questions as well as rating scales addressing parents' socialization of their children's math development and, more specifically, how they played the board game with their children. Four questions focused on socialization of children's math development: "How important is it that your child does math activities at home?", "How important is it that you help your child with math?", "How much do you enjoy math?", and "How good at math are you?" Response options ranged from 1 (*not very/not at all good*) to 5 (*very/very good/very much)*. Parents were also asked about the frequency with which their children engaged in 22 math-related activities, such as counting objects, playing board games, and writing numbers. Response options were 0 (*never/not at all*), 1 (*occasionally/less than once a week*), 2 (*often/at least once a week*), or 3 (*every day/almost every day*). A child engagement math composite was created by averaging the frequency scores across all activities. In order to understand how parents played the board games with their children, we asked them to describe where the game was played, who the participants were, and whether they used the counting procedure, if applicable. Parents were also asked whether they believed their children learned anything from playing the game.

Procedure.

Children's math skills. Children's early math skills were assessed pre- and post-intervention. Pre-intervention testing took place before any

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families received the game, and post-intervention testing took place after all families had completed their 5-week intervention period in order to assess all children at the same time of the year. Due to the amount of time it took to train all parents in the study, the beginning of the 5-week intervention period was unintentionally staggered. For this reason, there were approximately 4 months between pre- and post-intervention (*M* = 3.96 months, *SD* = 0.52 months). Children were tested individually by trained research assistants in empty classrooms in their Head Start centers and were given stickers for their participation.

Parent training. Families were randomly assigned to 1 of 3 intervention groups: *Chutes and Ladders* with the count-on procedure used by Ramani and Siegler[35] (experimental), *Chutes and Ladders* with standard game instructions (numeric control), or *Candy Land* (non-numeric control). All parents met individually or in small groups with the researchers at the children's schools for training and were given the appropriate game and instructions for their intervention group. We chose individual/small group meetings rather than one group meeting on the advice of the staff at the centers to maximize the number of participating parents. Parents in all groups were told that researchers "have learned…that [young children] learn a lot from playing games, especially games that they find fun and engaging." In the training session, researchers demonstrated how to assemble and play the game and fill out the game log. Parents were asked to play the game at least 3 times a week for 5 weeks. Parents received a log to record the dates they played the game, the number of minutes they played, and with whom the child played. We did not specify a specific amount of time per play session, but the log gave examples of 15 and 30 minutes of game play. Parents were asked to return the logs to their child's teacher at the end of the intervention.

Chutes and Ladders with count-on procedure. Parents in this condition were asked to use the count-on procedure which requires the players to count the numbers written on the game-board spaces instead of just the number spun on the spinner. They were asked to "count out loud the number printed on each game space. For example, if you are on space 6 and spin a 5, you should land on space 11. So as you move your game piece, place the game piece on each space while saying the number printed on the game space. So you would count, '7, 8, 9, 10, 11,' not '1, 2, 3, 4, 5.'"

Chutes and Ladders with standard games instructions. Parents in this condition were asked to play the game with the standard game instructions. No specific counting procedure was mentioned. However, if parents asked about how to count spaces, researchers told them "for example, if you spin a 6, you would count ‘1, 2, 3, 4, 5, 6’ and move one space for each number you count.”

Candy Land. Parents in this condition were asked to play the game with the standard game instructions. There was no discussion of counting, because this game uses colors and character images to dictate movement through the game board.

Parent interviews. Once game logs were returned, parents were asked to participate in a post-intervention interview. Interviews were conducted at the children’s Head Start centers by the primary researchers or trained assistants. Parents were given $10 in appreciation of their participation.

Results

Feasibility of home-based intervention. Fifty-two percent (n = 44) of parents returned logs indicating how long children played the game and with whom. Children played an average of 18 times (M = 18.44, SD = 7.20, Range = 5 – 35), for an average of 8 hours of total game play (M = 481.41 minutes, SD = 274.11 minutes, range = 130 – 1,617 minutes) during the 5-week intervention period. About half the children (57% of those whose parents returned logs) reportedly always played the game with an adult.

Forty percent (n = 34) of parents/guardians participated in post-intervention interviews about the game (14 in experimental condition, 8 in numeric control, and 12 in non-numeric control). The majority of parents did not play the game the way they were instructed. Of those interviewed in the experimental condition, only 50% (n = 7) reported using the count-on procedure correctly; 21% (n = 3) stated that they did not use the count-on procedure. Of those in the non-numeric control, 17% (n = 2) reported using counting when playing *Candy Land* (e.g., counting how many spaces they moved when they chose the yellow card).

Children’s math skills. Gender gaps in math performance are observed, albeit infrequently, as early as preschool[49,50] or kindergarten.[51,52] Therefore, we tested whether gender should be a covariate in analyses. We first used t-tests to determine whether there were differences on the variables of interest between boys and girls. Scores were higher for girls at pre-intervention for number line estimation, $t(78) = 2.05$, $p = .044$, Cohen’s $d = 0.46$, and higher for boys for numeral identification, $t(82) = 2.42$, $p = .018$, Cohen’s $d = 0.54$. At post-intervention, scores were higher for boys for magnitude comparison, $t(78) = 2.05$, $p = .044$, Cohen’s $d = 0.48$, and for numeral identification, $t(82) = 1.95$, $p = .055$, Cohen’s $d = 0.43$. We therefore included gender as a between-subjects variable in mixed ANOVAs comparing pre- and post-intervention scores. There were no interactions between gender and change in scores over time for any outcome measure, $p > .05$; accordingly, we did not include gender as a covariate in any subsequent analyses. We also tested whether age of child needed to be considered as a covariate. None of the analyses for age of child and changes in scores over time or interactions between age of child and type of intervention were statistically significant for any of the outcome measures, $p > .05$. Therefore, age was not considered as a covariate in any of the subsequent analyses.

Two questions were of interest in these analyses. One, was there significant pre- to post-intervention change in children's math skills? Two, did the changes vary by treatment condition? Mixed ANOVAS compared children's pre- and post-intervention scores, with condition as a between-subjects factor (see Table 1). Children's scores significantly increased from pre- to post-intervention for counting and numeral identification, but these changes did not differ across the three conditions.

Due to concerns during testing, preliminary examination of the number line estimation task data was done to determine whether children understood the task. If children chose the same location on the number line for 12 or more items (representing two-thirds of the items in the task) or did not complete 12 or more items, we concluded that they did not understand the task. The majority of children (approximately 90%) did not understand the task at both pre- and post-intervention testing. Thus, although number line estimation is included in Table 1, these results should be interpreted cautiously. There were not enough children who seemed to understand the task at both pre- and post-intervention testing to conduct a mixed ANOVA with a sample restricted only to those children.

Math home learning environment. The majority of the parents emphasized the importance of their children engaging in math activities at home. Eighty-five percent ($n = 28$) of parents believed that it was important/very important (4 or 5 on a 1 to 5 scale) for their child to do math at home, and 91% believed it was important/very important to help their child with math. Children engaged in math activities, including board games, on average, about once a week ($M = 1.78$, $SD = 0.44$). Thirty-five percent ($n = 12$) of parents reported that children never played board games at home, and about 47% ($n = 16$) played board games once a week to several times a week. Ninety-one percent ($n = 20$) of the *Chutes and Ladders* parents and, interestingly, 33% ($n = 4$) of the *Candy Land* parents believed their children gained math skills, such as counting and number recognition, from playing the game.

We conducted OLS regressions to test whether parents' beliefs predicted children's post-intervention math skills, controlling for pre-test scores. Given the small sample size, to minimize Type I error, we first computed zero-order correlations between parents' beliefs, frequency of engagement, and children's post-intervention outcomes. We conducted separate regressions for each belief that was significantly related to children's outcomes ($p < .10$). Controlling for pre-intervention scores, the extent to which parents enjoyed math, $\beta = .18$, $t(30) = 2.01$, $p = .053$, $\Delta R^2 = .033$, and the mean frequency with which children engaged in math activities at home, $\beta = .16$, $t(31) = 1.77$, $p = .087$, $\Delta R^2 = .024$, marginally predicted children's post-intervention numeral identification scores.

Table 1. Changes in math skills from pre- to post-intervention

	Pre-intervention Mean (*SE*)	Post-intervention Mean (*SE*)
Counting		
Chutes and Ladders Experimental (N=31)	8.71 (1.55)	9.74 (1.52)
Chutes and Ladders Control (N=27)	10.74 (1.66)	13.82 (1.63)
Candy Land (N=26)	9.54 (1.69)	11.69 (1.66)
Overall	9.66 (0.94)	11.75 (0.93)
Change	$F(1,81) = 6.64$, $p = .012$, partial $\eta^2 = .076$	
Group	$F(2,81) = 1.14$, $p = .325$, partial $\eta^2 = .027$	
Change X Group	$F(2,81) = 0.55$, $p = .577$, partial $\eta^2 = .013$	
Number Line Estimation[a]		
Chutes and Ladders Experimental (N=30)	41.07 (2.10)	46.37 (2.16)
Chutes and Ladders Control (N=25)	37.53 (2.30)	39.84 (2.36)
Candy Land (N=25)	37.20 (2.30)	41.16 (2.36)
Overall	38.60 (1.29)	42.46 (1.32)
Change	$F(1,77) = 5.43$, $p = .022$, partial $\eta^2 = .066$	
Group	$F(2,77) = 2.67$, $p = .076$, partial $\eta^2 = .065$	
Change X Group	$F(2,77) = 0.28$, $p = .757$, partial $\eta^2 = .007$	
Magnitude Comparison		
Chutes and Ladders Experimental (N=31)	9.48 (0.53)	9.97 (0.64)
Chutes and Ladders Control (N=26)	10.92 (0.58)	11.19 (0.70)

Candy Land (N=26)	10.54 (0.58)	10.85 (0.70)
Overall	10.32 (0.33)	10.67 (0.39)
Change	$F(1,80) = 0.77$, $p = .384$, partial $\eta^2 = .010$	
Group	$F(2,80) = 1.85$, $p = .164$, partial $\eta^2 = .044$	
Change X Group	$F(2,80) = 0.03$, $p = .972$, partial $\eta^2 = .001$	
Numeral Identification		
Chutes and Ladders Experimental (N=31)	4.65 (0.64)	5.84 (0.69)
Chutes and Ladders Control (N=27)	3.67 (0.69)	5.00 (0.74)
Candy Land (N=26)	5.23 (0.70)	6.19 (0.76)
Overall	4.51 (0.39)	5.68 (0.42)
Change	$F(1,81) = 30.92$, $p < .001$, partial $\eta^2 = .276$	
Group	$F(2,81) = 1.01$, $p = .369$, partial $\eta^2 = .024$	
Change X Group	$F(2,81) = 0.26$, $p = .775$, partial $\eta^2 = .006$	

Note. [a]Number line estimation scores represent average absolute error, so lower scores represent less estimation error. Additionally, because approximately 90% of children did not seem to understand the task, these results should be interpreted cautiously.

Discussion

This study attempted to adapt a successful classroom-based math intervention for use in the home. Of particular interest was whether parents would do what was asked, whether it would improve children's math scores, and whether children's math home learning environments were related to their early math skills. Although children, on average, showed significant change from pre- to post-intervention in counting and number identification, the effectiveness of the intervention did not vary across conditions. Furthermore, given that all children played a game (and some parents made the control game into a numbers game), we could not determine whether change was due to maturation or game playing. Another concern was that the majority of the parents did not perform the intervention as instructed. Study 2 used information from parent focus groups to revise the training conditions.

Study 2

In order to better understand why the intervention in Study 1 was not effective and prior to conducting the intervention in Study 2, we conducted

5 focus groups, each with 6 to 10 participants. Focus group participants were 40 parents (32 mothers, 6 fathers, and 2 grandmothers; 93% African American/Black) whose children attended 1 of 4 Head Start centers in Baltimore, Maryland. Unfortunately, none of the original parents from Study 1 were available to participate. However, the focus group participants were demographically similar to those in Study 1. A trained facilitator conducted the focus groups, and a trained assistant took notes. Focus groups were held at the Head Start centers and lasted about 1 hour. Audio recordings and notes were transcribed and coded.

A semi-structured script was used; it included questions about 3 main topics: typical family play activities (e.g., board games), potential barriers to adhering to count-on procedure, and additional help needed from researchers to increase child engagement. Responses were categorized into themes related to potential barriers to adherence and suggestions for improving future implementations.

Parents noted several potential barriers to playing the game and to using the count-on procedure. Many did not have a special time in their schedule to play board games, and their schedules were already too full to easily accommodate the addition of new activities. Many noted that they had more time to play the game on weekends than weekdays. In addition, parents believed that their children would not recognize all the numbers in the game (recall the game has numbers from 1 to 100). They also believed that their children would have limited attention for completing the game and/or for counting out loud the numbers on the game spaces. Parents indicated that giving children some form of incentive to reward compliance would be beneficial. When asked whether training children in the classroom might be beneficial, parents agreed that training in school would increase children's familiarity with the count-on procedure and the game itself. They mentioned that this also may help the children get excited about playing the game at home.

The redesigned interventions in Study 2 had the following conditions: *Chutes and Ladders* with stickers, *Chutes and Ladders* with child training, *Chutes and Ladders* with stickers and child training, and a no-game control condition. These are described in more detail below. We modified the tasks so that children did not need to complete the game (get to 100) to receive a sticker. Although parents mentioned that it would be useful to be given a total amount of time per week so they could be more flexible with how many days they played, we still asked parents to play the game, if possible, at least 3 times a week for 5 weeks. We reasoned that distributed practice would be better than mass practice and more consistent with the Ramani and Siegler[35] paradigm.

Method

Participants. Ninety-eight children (59% girls; 92% African American/Black) and their parents participated in Study 2. The mean age of children at pre-intervention was 4.07 years (*SD* = 0.58). Participants were recruited from 1 of 5 Baltimore City Head Start centers. None of the families in this study participated in either Study 1 or the focus groups.

Although all parents were invited to participate in post-intervention interviews, only 38 parents (97% African American/Black) did. Of parents interviewed, 82% (*n* = 31) were mothers, 13% (*n* = 5) were fathers, and 5% (*n* = 2) were grandmothers. Three parents each reported on 2 children for a total of 41 individual interviews. Two were mothers of 2 children in the study, and 1 was a mother of 1 child and an aunt of another child in the study. Eight percent of the parents (*n* = 3) had a bachelor's degree, 5% (*n* = 2) had an associate's degree, 47% (*n* = 18) had completed some college/vocational/technical school, 26% (*n* = 10) had graduated high school, and 11% (*n* = 4) had less than a high school education.

Measures.

Early math skills. The early math skills assessed in this study were the same as those in Study 1, with the exception of a few minor changes. Due to the difficulty children displayed with the number line estimation task in Study 1, 2 sample trials were added to the number line estimation task. For each sample trial, researchers presented children with a completed number line to demonstrate where the target number belonged. Researchers provided feedback until the child responded within a reasonable range of the correct position of the target number on a blank number line. Additionally, due to ceiling effects in Study 1, the range of numbers for the magnitude comparison and numeral identification tasks were increased to include 2-digit numbers. For magnitude comparison, 4 items with 2-digit numbers were added; therefore, the total number of items increased from 18 to 22. For numeral identification, 10 items with 2-digit numbers were added; the total number of items increased from 10 to 20.

Math home learning environment. In Study 1, all questions about parents' beliefs were limited to the post-intervention interview. To increase the number of parents responding in this study, several questions about parents' math socialization at home were included on the consent form, which parents completed prior to the intervention. Parents were asked to answer 4 questions focusing on socialization of children's math development: "How important is it that your child does math activities at home?", "How important is it that you help your child with math?", "How much do you enjoy math?", and "How good at math are you?" Responses to 2 questions—"How important is it that your child does math activities at home?" and "How important is it that you help your children with math?"—were highly correlated, $r(92) = .789$, $p = <.01$, and were therefore summed for use in further analyses. This variable was called summed importance of math. Response options ranged from 1 (*not very/not at all good*) to 5 (*very/very good/very much)*. Parents were also asked, "How often does your child play board games at home?" To increase response variance, response options were expanded from 0 to 3 in Study 1 to 1 (*never/almost never*) to 5 (*every day/almost every day*) in Study 2. Ninety-five percent ($n = 93$) of parents completed the questions included on the consent form.

As described in the Participants section, upon completion of the intervention, 38 parents (representing 41 children) completed the full interview about children's math home learning environment as described in Study 1 (with the omission of the math socialization and engagement items from the consent form).

Procedure.

Children's math skills. As in Study 1, children's early math skills were assessed pre- and post-intervention. On average, testing sessions were separated by approximately two months (M = 1.91 months, SD = 0.36 months). Children were tested individually by trained research assistants in empty classrooms or quiet areas in their Head Start centers and were given stickers for their participation.

Intervention. Head Start centers were randomly assigned to 1 of 4 conditions: sticker chart, child training in school, sticker chart with child training in school, or a no-game control condition. True random assignment by child was not done to prevent possible contamination across conditions. Parents in all intervention conditions were trained, individually or in small groups, depending upon their availability, to play *Chutes and Ladders* using Ramani and Siegler's[35] count-on procedure (see Study 1). As in Study 1, in the parent training session, researchers demonstrated how to assemble and play the game and fill out the game log. Parents were asked to play the game at least 3 times a week for 5 weeks. Each parent received a log to record the dates they played the game, the number of minutes they played, and with whom the child played. Parents were asked to return the logs to their child's teacher at the end of the intervention.

In contrast to Study 1, only *Chutes and Ladders* was used in the intervention. Parents in the treatment conditions were given *Chutes and Ladders* during parent training to use during the intervention period. They were allowed to keep the game once the study ended. Parents in the control condition received *Chutes and Ladders* after post-intervention testing was completed.

Sticker chart. Parents of children in this condition received a motivational sticker chart and colorful star stickers during the training session. The sticker chart used a 10 x 15 space grid design with the rows increasing in increments of 10. There were enough spaces on the sticker chart and enough stickers provided for children to play the game to completion during each of the recommended 15 game-play sessions. Parents were taught how to incorporate the sticker chart into game play. Parents were told that “stickers are a great way to keep your child’s attention during the game” and to “use the…sticker chart each time you and your child play *Chutes and Ladders*.” Parents were instructed that children should earn a sticker on their chart each time they passed an interval of 10. They were given the example, “If your child lands on the ladder on space 28 and moves up to space 84, your child would earn 6 stickers for passing 30, 40, 50, 60, 70, and 80.”

Child training in school. After parent training was completed and *Chutes and Ladders* was sent home, children were trained on how to play the game. Children were trained by the researchers in groups of 3 to 4 children in quiet areas in the Head Start centers. Children were taught how to play *Chutes and Ladders* with the count-on procedure (see Study 1 for specific instructions). Each child was given the opportunity to take 1 to 2 turns playing the game with specific focus on using the count-on procedure. Children were encouraged to watch each other play the game and ask researchers questions if they did not understand.

Sticker chart with child training in school. Parents of children in this condition received the sticker chart during training. After parent training was completed, children in this condition were trained in school using procedures described above.

Control. Neither parents nor children were trained in the control condition. Testing took place at the same time as the pre- and post-intervention testing in the treatment conditions.

Parent interviews. Interviews were conducted at the children’s Head Start centers by the primary researchers or trained assistants. Parents were given ten dollars in appreciation of their participation.

Results

Feasibility of home-based intervention. Fifteen percent (n = 15) of parents returned logs indicating how long their children played the game and with whom they played. Children played an average of 16 times (M = 16.00, SD = 9.65, range = 2 – 35) for an average of 9 hours total game play (*M* = 561.40 minutes, *SD* = 600.73 minutes, range = 50 – 2,454 minutes) during the 5-week intervention period. Fewer than half the children (47%) reportedly always played the game with an adult.

Forty-two percent (*n* = 41) of parents participated in post-intervention interviews (14 from sticker condition, 16 from child training condition, and 11 from sticker with training condition). Although more parents in this study reported using the count-on procedure than in Study 1, a nontrivial percentage did not. Sixty-three percent (*n* = 26) of parents interviewed reported playing the game with the count-on procedure as requested. Thirty-seven percent (*n* = 14) of parents indicated that they did not play the game using the count-on procedure. Several parents described experiencing some difficulty in having their child adhere to the count-on procedure. One mother said, "…she seemed like it [was] kind of hard for her to grasp…once you get your numbers and start counting, start counting from where we left off [as] opposed to 1, 2, 3 counting the spaces…. She seemed to improve, but you know she had to have several reminders." Thirty-two percent (*n* = 12) of parents noted that their children's unfamiliarity with larger numbers (numbers beyond 1-10) was a challenge. One mother explained, "…I would say the hardest part for her is because [child's name] at this point she can't really count past 30. So it was kind of hard for her to get used to instead of saying, 'okay I'm on 30, so let me say 1, 2, 3, 4, say 31, 32.' You know it was kind of hard for her to catch onto that, but she got the hang of it eventually."

Children's math skills. As in Study 1, preliminary analyses were conducted to see if gender should be considered as a covariate. *T*-tests determined whether there were differences on the variables of interest between boys and girls. Scores were higher for girls at post-intervention for counting, $t(95) = -2.43$, $p = .017$, Cohen's $d = 0.48$. We therefore included gender as a between-subjects variable in mixed ANOVAs comparing pre- and post-intervention scores. There were no interactions between gender and change in scores over time for any outcome measure, $p > .05$; therefore, gender was not included as a covariate in any subsequent analyses.

Consistent with analyses in Study 1, we considered the need to include age of the child as a possible covariate. None of the analyses for changes in scores over time associated with age of child, nor were interactions between age of child and type of intervention statistically significant for any of the outcome measures, $p > .05$. Therefore, age was not considered as a covariate in any of the subsequent analyses.

As in Study 1, analyses focused on 2 questions. One, was there significant pre- to post-intervention change in children's math skills? Two, did the changes vary by treatment condition? Mixed ANOVAS compared children's pre- and post-intervention scores, with condition as a between-subjects factor (see Table 2). For numeral identification, a significant increase was observed in children's performance from pre- to post-intervention regardless of condition. For number line estimation, there was a significant interaction between change and condition. Children in the stickers with training condition significantly improved their estimation accuracy from pre- to post-intervention. In contrast, the control group showed a decrease in accuracy from pre- to post-intervention.

Due to children's difficulty understanding the number line estimation task, we used the same strategy described in Study 1 to screen for children's understanding of the task. In a second set of analyses, we restricted the sample to children who appeared to understand the number line estimation task at both pre- and post-intervention. This resulted in a sample containing 43 children. Due to the small sample size, we consolidated all of the treatment conditions into one treatment group (n = 23). Analyses with the restricted sample showed a similar pattern of results to analyses with the full sample of children. There was a significant interaction between change in performance and condition, such that children in the treatment condition showed improved accuracy, whereas the control group did not, $F(1,41) = 7.61$, $p = .009$, partial $\eta^2 = .16$.

Table 2. Changes in Math Skills from Pre- to Post- intervention

	Pre-intervention Mean (*SE*)	Post-intervention Mean (*SE*)
Counting		
Stickers (N = 23)	7.56 (1.73)	8.65 (1.38)
Stickers with training (N = 22)	11.32 (1.77)	10.64 (1.41)
Training (N = 22)	13.68 (1.77)	15.59 (1.41)
Control (N = 30)	11.10 (1.53)	12.82 (1.20)
Overall	10.92 (0.85)	11.97 (0.68)
Change	$F(1,93) = 2.45$, $p = .121$, partial $\eta^2 = .026$	
Group	$F(3,93) = 3.64$, $p = .016$, partial $\eta^2 = .105$	
Change X Group	$F(3,93) = 0.80$, $p = .498$, partial $\eta^2 = .025$	
Number line estimation		
Stickers (N = 22)	29.14 (2.09)	30.76 (2.17)

Stickers with training (N = 21)	35.59 (2.14)	28.63 (2.22)
Training (N = 21)	29.98 (2.10)	27.80 (2.17)
Control (N = 28)	21.11 (1.86)	24.44 (1.92)
Overall	28.95 (1.03)	27.91 (1.06)
Change	$F(1,89) = 0.84$, $p = .350$, partial $\eta^2 = .010$	
Group	$F(3,89) = 5.70$, $p = .001$, partial $\eta^2 = .161$	
Change X Group	$F(3,89) = 4.23$, $p = .008$, partial $\eta^2 = .125$	
Magnitude Comparison		
Stickers (N = 23)	11.09 (0.74)	11.17 (0.85)
Stickers with training (N = 22)	13.14 (0.75)	12.60 (0.86)
Training (N = 22)	13.23 (0.75)	14.50 (0.86)
Control (N = 30)	12.13 (0.65)	13.00 (0.74)
Overall	12.40 (0.36)	12.82 (0.42)
Change	$F(1,93) = 1.75$, $p = .189$, partial $\eta^2 = .018$	
Group	$F(3,93) = 2.39$, $p = .074$, partial $\eta^2 = .072$	
Change X Group	$F(3,93) = 1.56$, $p = .205$, partial $\eta^2 = .048$	
Numeral Identification		
Stickers (N = 23)	4.91 (0.97)	5.65 (0.95)
Stickers with training (N = 22)	4.68 (0.99)	5.55 (0.97)
Training (N = 21)	7.62 (1.02)	8.43 (1.00)
Control (N = 30)	6.43 (0.85)	7.97 (0.83)
Overall	5.91 (0.48)	6.90 (0.47)
Change	$F(1,92) = 19.90$, $p < .001$, partial $\eta^2 =.178$	
Group	$F(3,92) = 2.31$, $p = .081$, partial $\eta^2 = .070$	
Change X Group	$F(3,92) = 0.81$, $p = .492$, partial $\eta^2 = .026$	

Math home learning environment. Ninety-five percent of parents ($n = 93$) completed the 4 socialization questions included on the consent form. The majority of parents (82%, $n = 76$) reported that it was important/very important (4 or 5 on a scale of 1 to 5) for their child to complete math activities at home, and 89% ($n = 83$) reported that helping their child with math activities was also important/very important. Parents noted that their children engaged in math activities, including board games, once a week to several times a week ($M = 2.44$, $SD = 0.63$) at home. Ten percent ($n = 9$) of parents reported that children never played board games at home. Sixty percent ($n = 56$) reported that their child played board games sometimes; approximately 29% ($n = 27$) of parents indicated that their children played board games every day/almost every day.

Of parents interviewed, 58% (n = 22) reported improvement in their child's counting ability as a result of playing *Chutes and Ladders*. Recall that children's counting skills, on average, did improve significantly but that there was no difference across conditions. Thirty-seven percent (n = 14) reported observing improvement in their child's number recognition abilities. However, we did not find this in our statistical analyses. Parents also noted improvement in other areas not related to math skills including: patience (24%), taking turns (18%), sharing (13%), handling losing better (7%), and following directions (5%). About a third of the families (32%) reported enjoying playing *Chutes and Ladders* with their child.

Logistic regressions were conducted to consider if parent beliefs predicted compliance to the count-on procedure. Regressions were conducted individually for each belief (summed importance of math, how much parents enjoy math, and how good parents are at math); all regressions were nonsignificant, $p > .05$.

OLS regressions examined the associations between parents' beliefs and their children's post-intervention math skills. We conducted separate regressions for each belief that was significantly correlated with children's outcomes. Controlling for pre-intervention scores, performance on post-intervention magnitude comparison was significantly predicted by the summed importance of math, $\beta = -.184$, $t(89) = -2.58$, $p = .012$, $\Delta R^2 = .034$.

Discussion

Although more parents complied with the intervention instructions in this study than in Study 1, a sizable percentage did not do so. Parents' beliefs about their role in their children's learning and how much they enjoyed math were not associated with whether they complied with the intervention. The issue of the feasibility of this type of intervention is discussed again in the General Discussion section.

Children, regardless of their assigned condition, showed growth from pre- to post-intervention on numeral identification. Children in the treatment condition, particularly the stickers with child training in school condition, showed improvement from pre- to post-intervention in number line identification.

There was only one significant association between parents' beliefs and children's math skills, after controlling for pre-intervention scores. The summed importance of math (the composite of ratings for the importance of child engaging in math at home and parents assisting with math) was negatively associated with children's magnitude comparison scores. The negative association is difficult to explain but may reflect that parents are more likely to emphasize math activities and be directly involved in such activities with their children if they believe their children are displaying some weaknesses in that area.

These findings were not wholly consistent with those of Ramani and Siegler.[35] However, the children in this study were younger than the children in the Ramani and Siegler study.[35] Perhaps some of the children in the current study were too young to benefit from the intervention. To test this, we conducted analyses using a sample limited to children who were at least 4 years old. The pattern of results was the same as with the full sample. Thus, children's age was not the reason for our results.

General Discussion

The 2 studies in this paper addressed the feasibility and effectiveness of adapting a successful classroom-based board game intervention for use in Head Start families' homes. The study was motivated by the need to decrease the math achievement gap between low- and middle-income children that is present even at the start of formal schooling.[2,11] The intervention involved giving children the commercially available numeric board game, *Chutes and Ladders*, and instructing parents how to play it using a count-on procedure developed by Ramani and Siegler.[35] Previous classroom-based studies using the count-on method had positive effects on children's counting, number line estimation, magnitude comparison, and numeral identification skills. However, our home-based adaptation was less successful in fostering mathematics skills. We discuss below several issues related to feasibility and implementation. We make the case that although board games appear to be well received by families as a method of intervention, several adjustments would need to be made to make this intervention successful**.** We suggest some such adjustments in the final section of the paper.

Feasibility

Many prior math home-based intervention studies have utilized extensive parent training or provided costly tools to parents.[16,40] However, such approaches are not realistic for larger-scale implementation. Our goal was to see if we could improve children's math skills with less intensive training and by providing less expensive tools. Parents, particularly those from low-income backgrounds, frequently have very limited time to devote to being trained. Moreover, neither they nor their children's schools have extensive financial resources. *Chutes and Ladders* is inexpensive and commercially available; and the count-on procedure is fairly simple and easily added to the game.[35,44] Accordingly, we expected that parents would be able to successfully implement the intervention in their homes to enhance their children's math learning.

The parents who participated in these 2 studies were excited to receive the game for their children, and many said they were familiar with the game. Nevertheless, our findings suggest that simply providing parents with some training at their children's Head Start center and sending the board game home was not effective. Consistent with what has been found in other studies,[14] only about half the parents in the present set of studies actually returned logs or participated in post-intervention interviews (50% Study 1, 63% Study 2). And only half of those parents reported playing the game the way they were instructed. Many of the parents reported that they did not have the time to play and instead the game was played with siblings. Another key concern voiced by the parents was that the game was too hard for their children. Although the game is marketed to children 3 years and older and was suggested as compatible with the one played by children in Ramani and Siegler,[35] few children in our sample were capable of counting to 100 (the highest numbered space in *Chutes and Ladders*). The highest any child counted in pre-intervention testing was to 49 (Study 1) or 50 (Study 2). The mean was about 10 (Study 1) or 11 (Study 2). Parents mentioned that the additional demands of using the count-on procedure to count higher numbers than the child was able to recognize was too challenging. The "chutes" involved in Chutes and Ladders also proved to be an unintended barrier to implementation. Parents noted that when children landed on a "chute" and had to go backwards, they became upset, which hindered their ability to continue playing and detracted from a focus on numbers. Unfortunately, we were not aware of any other commercially available games that used an appropriate number line format.

Effectiveness of the Intervention

Despite many parents not complying with the intervention, children showed some improvement from pre- to post-intervention testing. Children, regardless of condition, showed improvement from pre- to post-intervention on counting (Study 1) and numeral identification (Studies 1 and 2). The math experiences children had at school and home during the course of the intervention may have influenced their math skill development. Counting was a commonly reported activity for these children. About 85% reportedly counted objects almost every day. Also, parents in the control condition in Study 1 may have positively influenced their children's math development by counting spaces while they were playing *Candy Land*, although they were not instructed to do so.

Our findings are not in keeping with those of Ramani and Siegler[35] or Siegler and Ramani.[45] They found significant improvement on all the tasks for children in the experimental group. We found improvement (moderate to large effect) associated with the intervention only on the number line estimation task in Study 2. We attribute the differences in findings between our studies and theirs to differences in child training. In the Ramani and Siegler studies,[35] researcher-trained personnel taught children to use the count-on procedure and supervised them while they played the game. Because we did not observe parents training their children at home, we cannot definitively say how effective they were at teaching children to use count-on. However, we do know that many reported that they did not use the count-on procedure when playing the games with their children. In addition, the Ramani and Siegler studies[35] only used the numbers 1 to 10 in the training. In our study, the numbers in *Chutes and Ladders* went to 100, which was higher than most children could recognize or count.

Children's Math Home Learning Environment

Documenting children's math home learning environment is important because it allows us to learn more about the resources available to children,[14] which may impact the effectiveness of an intervention. Researchers have voiced concerns that low-income children have more limited math experiences at home than middle-income children,[11,27] something that may be related to income-based gaps in math achievement.[53] Moreover, it is not enough to document what children are doing; we also need to document parents' beliefs about children's learning because such beliefs are associated with practices.[27] The majority of parents in Studies 1 and 2 strongly endorsed the importance of children engaging in math activities at home and assisting their children with such activities. Nevertheless, it appears that children were not engaging in math activities as often as would be beneficial and many had limited experience with math board games, something thought to be important for magnitude knowledge.[35] Children in Study 1 reportedly engaged in math activities on average about once a week. Over a third of parents reported their children never played board games (aside from the ones used in our study). Children in Study 2 engaged in math activities once to several times a week, and many had limited experience playing board games prior to our intervention. These findings are consistent with an emphasis on the need to increase the number and amount of math experiences children from low-income backgrounds have at home.

Limitations

There are several factors that may limit the generalizability of the findings. One, almost all of the families in this study were African American/Black. This is consistent with the population in the Head Start centers where the study took place. Although we have no reason to suspect that findings would differ with different racial/ethnic groups, this should be considered in future studies. Two, our knowledge of what went on in the home (how frequently the children played the game and with whom) is based on parents' self-reports and subject to reporting errors and bias. Similarly, reports of the frequency with which children engaged in math-related activities at home was based on parents' reports. Three, due to low response rates, data about children's activities and how the board game was played are based on fewer than half the children. Such a low return rate is typical of studies such as this one.[14] Nevertheless, parents who returned logs and participated in the interviews may differ in some systematic way from those who did not. Despite these limitations, the data provide important information about the effectiveness of a home-based math intervention.

Educational and Policy Implications

Although increasing parent involvement in their children's education is a goal of educators and policy makers (e.g., US Department of Education[53], coming up with ways that are cost-effective and that parents will implement can be difficult. We discuss below 2 difficulties we experienced that have important educational and policy implications and possible solutions. One, the one-time training we provided to parents was not enough to ensure appropriate implementation in the home. Research shows that when families and schools frequently exchange information, parents are more likely to provide ongoing support for their children's education (e.g., Sheldon and Epstein[37]). Schools could implement programs where children learn to play math games in school and take them home on the weekends to play with parents. This kind of take-home activity could be especially beneficial for low-income families who may have few math-related games and materials. To be successful, however, it would need ongoing communication between the teachers and the parents. It might even be interesting to consider a game lending library, something that has been done successfully using books (e.g., Serpell et al[47]). Given that the game used in this study appeared overly complicated for our sample of low-income preschoolers, it is important that educators look for games that are very simple and clearly numerically oriented. Unfortunately, there do not appear to be many commercially available linear number board games that are optimally suited for fostering the math skills (e.g., magnitude knowledge) of this age group of children. Not only was *Chutes and Ladders* too complex for this age group and not only did it have many distractions (e.g., the chutes) that took away from the focus on numbers, but many parents also reported that the game was not sufficiently engaging for their children. Creating custom board games with a number line format that can be printed and laminated would be low cost and potentially more effective than finding commercially available board games for preschoolers.

Two, future interventions with parents should emphasize the importance of specific math activities for children's math learning. Although we mentioned the importance of playing board games in our instructions to parents, we did not explicitly state the benefits of playing such games. When parents are aware of the specific outcomes associated with their home-based practices, they are more likely to implement them. For example, Niklas et al[14] used a training procedure that emphasized the importance of math and provided examples of commonly occurring everyday activities that involved math. Their training focused on counting activities and teaching numbers, which probably had lower demands than our training procedure. Children in the trained condition increased both the number of math activities they did at home and their scores on various counting and number value tasks compared to an untrained control group. Thus, sharing information with parents about activities they can do at home to foster their children's math skills can be an easy and effective way to promote family engagement and potentially close the math achievement gap. Looking for ways to effectively involve parents at home has implications beyond this study. That is, Alexander et al[54] have argued that children, particularly those from low-income backgrounds, lose some of what they have learned during the school year during the long summer vacation. This is particularly true for math skills. Thus, finding ways for parents to be successfully involved in assisting their children's math development is critical to closing income-related achievement gaps.

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