INCREASING MATH TALK IN ADULT-CHILD INTERACTIONS THROUGH GROCERY STORE SIGNS

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There is a persistent gap in math abilities between children from low socioeconomic (SES) families compared to children from high-SES families. Interventions to reduce this gap are often expensive and not easily implemented. This study examined the efficacy of a cost-effective intervention in grocery stores in order to try and increase the number of math-related adult-child conversations to increase children's school readiness. We created and placed signs about general language and math in grocery stores in a low-SES neighborhood and a high-SES neighborhood that encouraged conversations between adults and children while shopping. Researchers used observational coding methods to see how these signs naturally influenced conversations. When signs that contained prompts to engage in math conversations were present there was an overall increase in conversations about math compared to the general language signs or when no signs were posted. When signs were present in the low-SES location, there was an increase in conversations about math between adults and children, whereas the signs did not have this effect in the high-SES location. This study demonstrates the benefits of implementing a cost-effective intervention in a natural environment that could increase math conversations and school readiness in children, especially from low-SES families.

TABLE OF CONTENTS

LIST OF TABLES

PREFACE

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1.0 INTRODUCTION

Some early academic skills, like math, develop through talk and play with caregivers before proper schooling. Mathematics can be referred to as numeracy, which has been defined as the use of mathematics to meet various challenges in an individual's environment (Botha, Maree, & de Witt, 2005). In early childhood, concepts of numeracy tend to have a focus on numbers, measurement, space, and shape (Botha et al., 2005). Children from low-socioeconomic status backgrounds tend to show an inequality in cognitive ability, beginning school with lower academic performance when compared to those from mid- or high-SES backgrounds. Many of these disparities result from a lack of opportunity for academic development in children's early years before entering school (Lee & Burkam, 2002).

Math proficiency at kindergarten entry level shows a significant gap between children from low- and high-SES backgrounds. In a study conducted to find differences in children with and without math proficiency in early education, students from low-SES families scored 0.48 standard deviations (SD) lower than students from higher SES families (Galindo & Sonnenschein, 2015). When SES was not a factor in the data and it was analyzed between all the children in general, the children who began kindergarten with proficiency in math, received math scores 0.43 SDs higher than children who did not have math proficiency when beginning (Galindo & Sonnenschein, 2015).

Childhood poverty affects nearly 15 million children in the United States currently living with families that earn income below the federal poverty line (Hanson et al., 2013). Along with this, children living in poverty are often exposed to more family turmoil, violence, and instability and receive less social support (Hanson et al., 2013). Social interaction is important for children and plays a critical role in early brain development (Blakemore, 2010). Living under the national poverty line can cause problems such as parents not spending enough social time with children due to time constraints on working hours from one or multiple jobs. Less social interactions deprive children of important learning opportunities that influence their later academic success.

The amount that parents talk to their children about math, i.e. "math talk," is highly predictive of children's later math skills. More math talk between families could greatly help math development in children. During the preschool years, learning math skills is extremely important for predicting growth in mathematics (Jordan, Kaplan, Locuniak, & Ramineni, 2007). In a report on a longitudinal study, it was found that children's numeracy and mathematical skills in kindergarten are highly predictive of their performance and test scores at the end of Grades 1 and 2 (Aunola, Leskinen, Lerkkanen, & Nurmi, 2004). In another longitudinal study, researchers found that elementary school students' knowledge of concepts of fractions and division predicted overall mathematics achievement years later, up to high school (Siegler et al., 2012). With all of these reports, it can be seen that learning math skills in years before schooling is highly predictive of growth in mathematics, which can lead to better math achievement in kindergarten and subsequent early education years. It has also been found that differences in mathematical knowledge that is present in preschool and kindergarten are stable through fifth grade. These differences in children's mathematic knowledge are more stable than differences in reading and other academic subjects (Siegler et al., 2012). Since math is a necessary part of children's education, increasing adult-child conversations about math could improve these academic abilities and later math achievement.

In order to decrease early academic gaps in children, it is important to consider possible contributing factors in years before schooling with in-home activities and interactions with caregivers. Blevins-Knabe and Musun-Miller (1995) found that the higher level of mathematical activities conducted between parent and child, the higher percentile score the child received on standardized tests of mathematics. This suggests that the more math-related activities in adult-child interaction, the higher the math achievement. There is notable variability in the amount of math talk in homes (Gunderson & Levine, 2011; Levine, Suriyakham, Rowe, Huttenlocher, & Gunderson, 2010; Susperreguy & Davis-Kean, 2014). While some parents use minimal mathematical language, other parents teach their children simple counting and addition. A study by Benavides-Varela et al. (2016) found that children's performance on number line or comparison tasks were not affected by numerical information learned in their home family environment. However, it was found that numerical information learned at home influenced counting ability, which is a fundamental skill in later arithmetic learning. Results from a study conducted by Boonen et. al, (2011) indicate that children's initial number sense level is the strongest predictor of later math achievement. This finding highlights the importance for children to experience mathematics before entering kindergarten (Boonen et. al, 2011). Increasing exposure to counting and other verbal numerical skills at home and education before kindergarten gives rise to further development of early math concepts (Boonen et. al, 2011).

A study by Boonen, Kolkman, and Kroesbergen (2011) looked at the role of teachers; math talk with children after they have started their early school years. It was found that there is an overall relationship exists between teachers talking to children about math and children's number sense scores at the end of the school year. Among the many different forms of math skills, children often learn counting skills as one of the first, which was shown by the particular affect in children's scores on tasks that measure counting skills (Boonen et. al, 2011). Moreover, a study by Hart and Risley (1992), suggests that the amount of math talk directed towards kindergartners has a positive impact on the acquisition of their mathematically relevant language. These findings suggest that teachers' use of numerical language increase children's ability to understand different number skills like counting, and could predict later academic achievement.

Adults' math talk is important for children's acquisition of verbal numerical skills, but using gestures can also increase children's abilities in counting. Lafay et al. (2013) found that the integration of motor functions of fingers during early counting and calculation could help children acquire numerical information. Children in first grade were much more likely to use gestures to help with counting and calculations than children in preschool or kindergarten (Lafay et al., 2013).

In a recent study conducted by Ridge and colleagues (2015), a cost-effective intervention was implemented into grocery store settings to promote adult-child conversations to aide language development and school readiness. The intervention included creating and displaying signs in different places inside the stores that families could see and talk about. They found that when signs were introduced to grocery stores in low-SES neighborhoods, the amount of talking and the quality of conversation in the parent-child interactions was significantly increased compared to when the signs were not present. Adults and children were four times more likely to converse when signs were present, bringing these interactions to the same level of those in the mid- to high-SES range (Ridge, Weisberg, Ilgaz, Hirsh-Pasek, & Golinkoff, 2015). The study focused on language development and numerical language was part of the interaction coding system; however, the signs did not include any math-specific questions promoting math talk. The current study will fill this gap in the literature.

1.1 LIMITATIONS IN CURRENT LITERATURE

There is a lack of study on early mathematical teachings and ability in comparison to literature relating to early language acquisition. The breadth of research in childhood early education focuses on language acquisition, which is important for school readiness, but exposure to math is also beneficial. It has been found that children's early acquisition of numerical information within a family environment significantly predicts the child's later mathematical ability, including solving numerical problems, counting abilities, and identifying one-to-one correspondences between sets (Benavides-Varela et al., 2016). With this research, children could be better prepared for academic success in language and mathematics. Promoting math talk could lead to higher academic readiness in children from both low- and mid- to high-SES backgrounds. Thus, it is crucial to understand how this can be implemented in everyday activities.

1.2 RESEARCH AIMS

This study aims to find subtle ways to promote adult-child conversations about math in a natural environment in order to boost children's readiness for school. The natural setting of grocery stores was based on data indicating that families spend about one-third of their income on food (Gershoff, 2003). The present study consisted of three different conditions: a baseline condition with no novel signs displayed, a math-sign condition in which math-specific prompts were displayed on various signs throughout the store, and a general conversation condition in which general prompts were displayed on various signs throughout the store to promote general conversations between adults and children. The general conversation condition was included to ensure that increases in math talk were specific to the math-related prompts and not the general conversation prompt. In the no sign condition, no signs were placed in order to determine how much parents talk to their children when there are no prompts to encourage conversation. This condition helped solidify if the signs have any overall impact on increasing conversation in adult-child interactions. The study investigated (1) whether or not integrating a low-cost intervention into an everyday environment increased adult-child conversations about math, and (2) whether or not an overall difference in conversation between adults and children from lower and higher SES areas occurred. It is hypothesized that shoppers will be influenced by the implementation of signs. A positive increase in adult-child interaction and conversations is hypothesized, especially in low-SES locations. It is also hypothesized that the math-specific signs will promote conversations about math while the general signs will promote conversation about topics other than math. Both signs will promote more conversation than the no sign condition.

2.0 PROCEDURAL METHOD

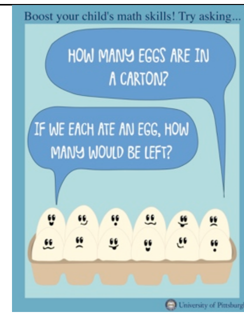
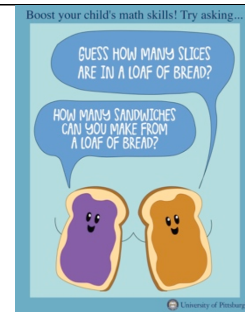
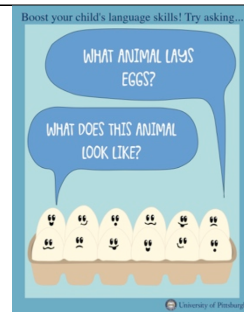
The study consisted of a total of three different observation conditions: math-specific, general conversation, and no sign. A sign stating, "Talking to your child is important for preparing them for school!" was placed at the front of the store in all conditions. In the math-specific condition, signs were placed in areas of the store where common products and foods are bought (i.e., bread, eggs, and milk) that promote conversation about math. The signs contained colorful pictures with text that encouraged parents to ask their children a question involving numbers (e.g., "How many glasses of milk do you drink each week?"; "How many sandwiches can we make with one loaf of bread?") (see Table 1). In the general conversation condition, signs were placed in the same food sections, that encouraged conversation about a topic other than math (e.g., "Where does milk come from?"; "What animal lays eggs?") (see Table 1).

Each of the three conditions were completed in both store locations to have an even amount of data collected. I was the only research assistant who collected the data. I stationed one sign location (e.g., bread, milk, or eggs) per visit in order to avoid scoring a family more than once. In each aisle where a sign was placed, I only coded the families in hearing distance. An auditory perimeter was set around each sign to indicate when I started coding the family's interactions and when I stopped. When families entered the perimeter, the coding began and stopped once the family was out of the perimeter and no longer able to be heard. There were three sign locations for each of the three conditions, which is a total of at least nine visits to every store location. If there was not enough data collected in one of the visits (e.g., too few shoppers with children in the target age range), there was an increase in the number of visits to that store in order to keep the data evenly distributed across all conditions. Ten families (referred to as were coded at each sign area (i.e., bread, eggs, and milk), for each condition, and store location, which is a total of 180 families. This was to ensure an equal amount of data for the three conditions (math-specific, general conversation, and no sign), as well as equal amount of data from low-SES and mid- to high-SES locations.

All of the data was collected on weekend days (i.e. Saturday and Sunday) and the times of data collection were alternated between the two days. For example, when I completed observations at the low-SES store in the morning on Saturday, I would wait and complete the other observations at the low-SES store on the Sunday night. I did this for all of the observations to ensure that the data was counterbalanced.

While coding, I acted as though I was a customer shopping in the store in order to make the coding process more discreet to targeted families. An observational coding sheet was created in the online survey system Qualtrics to be accessible by any smart phone. The accessibility of coding on a phone allowed for the coding to be more natural and less suspicious to families, as it is common to see people on their phones in such a setting.

Table 1. Images of the signs for each condition and store area.

	Front of store	Milk aisle	Egg aisle	Bread aisle
Condition 1: Math-specific				
Condition 2: General conversation				
Condition 3: No Sign				

2.1 PARTICIPANTS

The participants in this study were children ages 2-5 and their accompanying parent(s) or caregiver(s). Ages of the children were estimated from appearance by observing researchers. I also recorded race/ethnicity and sex of all the participants based on physical characteristics. Of all observed children, 66 were judged to be male and 106 female. In addition, 7 were judged to be Asian, 79 Black or African American, 83 White, and 3 Hispanic or Latino. Of all observed adults, 49 were judged to be male and 123 female. In addition, 5 were judged to be Asian, 78 Black or African American, 87 White, and 2 Hispanic or Latino. When there was more than one child in the family that looked in the appropriate age range, I chose one to observe. When there was more than one adult talking to the child, I observed all speech directed at the target child from all the adults. Only one adult in each family was coded for sex and race, which was determined by which adult was talking with the child the most. There were 36 families that had at least one older child in addition to the observed target child, 23 families that had two parents/adults, and 134 families with one adult and one child. Due to the nature of a naturalistic observation, informed consent was not required from any of the adults or children.

Families were observed in grocery stores of different SES levels. SES of shoppers in each store was determined by the zip code in which the store was located. A neighborhood of Philadelphia, Pennsylvania was considered low-SES where the average household annual income is below the poverty line by more than 50 percent. A mid- to high-SES neighborhood was determined where average household annual income is below the poverty line by less than 10 percent. The findings of average annual income are based on Census data collected by the 2011-2015 American Community Survey 5-Year Estimates with selected economic characteristics (U.S. Census Bureau, 2011).

2.2 CODING

Observations were coded the same way in all three conditions. The observer estimated the age, sex, and ethnicity of the children and adults. The observer also documented the number of conversational turns. Conversational turns were determined by how many pieces of information were spoken by the target child and directed to the target child. Every utterance from the target child counted as a single conversation turn. If an adult responded to the child or said something directed toward the child, then that was coded as one conversational turn. If there were multiple adults, each time one of them said something directed toward the targeted child, it was counted as a conversational turn. If the adults in the family were only conversing with themselves and did not include the child, no conversational turns were coded. Non-verbal gestures, like responsive head nods or shakes, were also included in conversational turns. The coding manual had a range of amount of conversational turns (i.e., 0, 1, 2-5, 6-9, 10+). Additional adults or children in the family were included in conversational turns when coding, but they were not included in any other codes. In addition, researchers coded who initiated the conversation and what the valence of the overall adult-child interaction was like. The valence was coded on a scale between very negative and very positive with three levels in between the extremes. The end of the coding sheet had a place for general notes for researchers to enter any information that may be outside of the strict codes and would be helpful or necessary for later analysis. For example, many of these notes were used to describe siblings or other adults in the family unit that were included in the conversational turns. These general codes allowed us to see if the use of signs was increasing the amount and quality of adult-child interaction compared to the baseline condition.

Two researchers observed the same 24 families (equally divided between conditions and locations) to assure reliability within the coded data. Out of the 24 double coded cases, 21 of them did not differ on any of the codes except age of the child, which makes the Interrater reliability at 87%.

2.2.1 PRODUCT

The signs did not promote any product over another; however, we did code whether the family put the product in their cart to determine if the signs prompted the family to purchase the pictured items. Conversation about the product being discussed was also included. When either the child or adult said the product name or did simple gestures like pointing to or picking up the product that was coded. When the conversation went into a deeper level of understanding like describing features, asking questions, or providing information beyond physical features, those were also coded.

2.2.2 PRICE

When the adult or child said the price of the product pictured on the signs, it was coded. Pointing to the price tag, and discussing the price were included as well. The price of the product was separated from math-specific conversation because it was considered to be more related to the product, not the signs promoting talk.

2.2.3 SIGN

Each sign had a character on it that resembled either bread, milk, or eggs. There were also two questions on every sign, except for the main sign in the front of the store. If the adult or child discussed the characters on the signs, read the questions, answered the questions, or elaborated and explained the questions further, it was coded.

2.2.4 MATH TALK

A description and examples of each type of math talk coded for is provided in Table 2. Types of math talk were coded differently if the adult or child used any types of gestures, like counting with fingers or pointing. No recordings or transcriptions of conversations were taken. All codes used a "yes" or "no" chart to simply indicate whether they occurred or not, but frequencies of each type of math talk were not coded.

Table 2. Description and examples of types of math talk between adults and children.

Type	Elicitation Description	Elicitation Example	Use of math talk description	Use of math talk Example
Uses a number word	Prompting or asking for a number word or amount of items in a set.	"There are how many gallons of milk in our cart?"	Simply stating any number or amount of items in a set.	"There are two gallons of milk in our cart."
Counting	Prompting or asking to count.	"Let's count together how many pieces of bread there are: 1, 2, 3, 4, 5…"	Reciting counting words, counting objects in a set.	"In this bag, there are 1, 2, 3, 4…12 slices of bread"

Calculation/Operations	Prompting or asking for performance of arithmetic operations and calculations like addition, subtraction, multiplication, or division.	“There are twelve eggs in a carton. How much would be left if we each ate one egg?”	Verbally performing arithmetic operations and calculations like addition, subtraction, multiplication, or division.	“There are twelve eggs in a carton and if I ate one and you ate one there would be 10 eggs left”

2.2.5 OFF TOPIC

Any conversation that was not about the product or math was coded as “off topic” information. This included conversations about school, friends, family, vacations, etc. Asking questions, using descriptive language, and giving information or explanation were all coded for in this section.

3.0 ANALYSIS

In Table 3 and Table 4, the percentage of adults and children who used each coded variable for math talk, at least once, is listed for each condition separately for each of the store locations. Note that only some of the codes used were analyzed here. The codes that were analyzed were math talk and conversational turns.

Table 3. Percentages of teachers in each of the three conditions (Sign Up Math, Sign Up General, and No Sign) who engaged in at least one instance of math talk in the low SES and high SES stores.

		Condition					
		Sign Up Math		Sign Up General		No Sign	
Speaker	Category	Low SES	High SES	Low SES	High SES	Low SES	High SES
Teacher	Uses a number word	55.6	40.7	20.0	17.9	20.0	20.0
Teacher	Elicits a number word	44.4	11.1	0.00	3.60	3.30	0.00
Teacher	Counts with pointing	11.1	11.1	3.30	0.00	3.30	0.00
Teacher	Counts without pointing	11.1	0.00	0.00	0.00	0.00	0.00
Teacher	Elicits counting	22.2	11.1	0.00	0.00	0.00	0.00
Teacher	Performs an operation with gestures	3.70	11.1	0.00	0.00	0.00	0.00
Teacher	Performs an operation without gestures	11.1	0.00	0.00	0.00	0.00	0.00
Teacher	Elicits an operation	7.40	7.40	0.00	0.00	0.00	0.00

Table 4. Percentages of children in each of the three conditions (Sign Up Math, Sign Up General, and No Sign) who engaged in at least one instance of math talk in the low SES and high SES stores.

		Condition					
		Sign Up Math		Sign Up General		No Sign	
Speaker	Category	Low SES	High SES	Low SES	High SES	Low SES	High SES
Child	Uses a number word	51.9	14.8	0.00	3.60	6.70	10.0
Child	Elicits a number word	3.70	0.00	0.00	0.00	3.30	0.00
Child	Counts with pointing	25.9	7.40	0.00	0.00	0.00	3.30
Child	Counts without pointing	3.70	0.00	0.00	0.00	0.00	0.00
Child	Elicits counting	3.70	0.00	0.00	0.00	0.00	0.00
Child	Performs an operation with gestures	7.40	0.00	0.00	0.00	0.00	0.00
Child	Performs an operation without gestures	0.00	0.00	0.00	0.00	0.00	0.00
Child	Elicits operation	0.00	3.70	0.00	0.00	0.00	0.00

3.1 MATH TALK DIFFERENCES BETWEEN THE CONDITIONS

We first looked at differences in each of the math talk categories for both teacher and child ("uses a number word," "elicits a number word," "counts with pointing," "counts without pointing," "elicits counting," "performs an operation with gestures," "performs an operation without gestures," and "elicits operation") across the three conditions (Sign Up Math, Sign Up General, No Sign). Pearson chi square tests were used for all analyses of math talk between the conditions. Overall differences were found between the three conditions for teachers' use of all math talk categories (all *p*s $< .036$). More teachers in the Sign Up Math condition used number words (48.1%) compared to teachers in the Sign Up General condition (19%), $X^2(1) = 10.77$, $p = .001$, and there was no difference between the number of teachers who used number words in the Sign Up General condition (19%) compared to the No Sign condition (20%), $X^2(1) = .02$, $p = .887$. There were also more teachers in the Sign Up Math condition that elicited number words (27.8%) compared to teachers in the Sign Up General condition (1.7%), $X^2(1) = 15.5$, $p < .001$. There was no difference between the number of teachers who elicited a number word in the Sign Up General condition (1.7%) compared to the No Sign condition (1.7%), $X^2(1) = .001$, $p = .981$.

Within categories relating to counting in the Sign Up Math condition, more teachers counted with pointing (11.1%) compared to those in the Sign Up General condition (6.3%), $X^2(1) = 4.21$, $p = .040$. More teachers in the same condition also elicited counting (16.7%) compared to those in the Sign Up General condition (0%), $X^2(1) = 10.51$, $p = .001$. There was no significant difference in teachers counting without pointing between the two Sign Up conditions (Math and General) $X^2(1) = 3.31$, $p = .069$. There was no significant difference between how many teachers counted with pointing in the Sign Up General condition (1.7%) compared to the No Sign condition (1.7%), $X^2(1) = .001$, $p = .981$, as well as no significant difference between how many teachers elicited counting in the Sign Up General condition (0%) compared to the No Sign condition (0%). Similar to the difference in teachers' math talk between the Sign Up Math condition and the Sign Up General condition, between the Sign Up general condition and the No Sign condition there was no significant difference in teachers counting without pointing $X^2(1) = .001$, $p = .981$.

Within categories relating to operations in the Sign Up Math condition, a similar pattern to the categories relating to counting in the Sign Up Math condition was found when compared to the Sign Up General condition. More teachers in the Sign Up Math condition performed an operation with gestures (7.4%) compared to those in the Sign Up General condition (0%), $X^2(1) = 4.46$, $p = .035$. More teachers elicited an operation in the Sign Up Math condition (7.4%) compared to teachers in the Sign Up General condition (0%) $X^2(1) = 4.46$, $p = .035$. Similar to the categories of counting, there was no significant difference in teachers performing an operation without gestures $X^2(1) = 3.31$, $p = .069$. When looking at differences in teachers' math talk between the Sign Up General condition and the No Sign condition, there were no significant differences in any of the categories relating to operations ("performs an operation with gestures," "performs an operation without gestures," and "elicits an operation") because none of these behaviors occurred.

Pearson Chi Square tests indicated no overall differences between the three conditions (Sign Up Math, Sign Up General, and No Sign) for children's math talk categories. There was also no significant difference between the two Sign Up conditions (Math and General) for the categories of "elicits a number word," "counts without pointing," "elicits counting," "performs an operation with gestures," "performs an operation without gestures," and "elicits an operation" (all *p*s > .050). For the categories "uses a number word" and "counts with pointing," there was a significant difference between the Sign Up Math condition and the Sign Up General condition. More children used a number in the Sign Up Math condition (33.3%) compared to children in the Sign Up General condition (1.7%), $X^2(1) = 19.84$, $p < .001$. There were also more children who counted with pointing in the Sign Up Math condition (16.7%) compared to the children in the Sign Up General condition (0%), $X^2(1) = 10.51$, $p = .001$. When looking at children's math talk in the Sign Up General condition compared to the No Sign condition, there were no significant differences in any of the categories.

3.2 SES DIFFERENCES IN MATH TALK

Using a Pearson Chi Square test, we examined differences of math talk between the low-SES location and the high-SES location across all three conditions (Sign Up Math, Sign Up General, and No Sign). For teachers, there were no significant differences in categories "uses a number word," "counts with pointing," "counts without pointing," "elicits counting," "performs an operation with gestures," "performs an operation without gestures," and "elicits an operation." However, there were more teachers who elicited a number word in the low-SES location compared to the high-SES location, $X^2(1) = 5.06$, $p = .025$. There we no significant differences for children when comparing the low-SES location and the high-SES location across all three conditions (Sign Up Math, Sign Up General, and No Sign).

We then examined differences in math talk between the low-SES location and the high-SES location for only the two Sign Up conditions (Math and General). The differences for teachers were the same as listed above for all three conditions as they were for the two Sign Up conditions. The only significant difference was that more teachers elicited number words in the low-SES location compared to the high-SES location, $X^2(1) = 4.34$, $p = .037$. When looking at the children's math talk data between low-SES and high-SES locations in the two Sign Up conditions (Math and General), more children used a number word in the low-SES location compared to the high-SES location, $X^2(1) = 4.76$, $p = .029$. All percentage differences between conditions, low-SES, and high-SES can be found in Table 3.

Finally, there were no significant differences found between the low-SES location and the high-SES location when looking at math talk in the Sign Up General condition and the No Sign condition (all *p*s > .050).

3.3 LEVEL OF GENERAL ENGAGEMENT WITH THE SIGNS

We looked at general engagement with differences in conversational turns between the child and adults in the family across all sign conditions (Sign Up Math, Sign Up General, and No Sign). Using a Pearson Chi Squared test, we found no significant differences across all three of the conditions for conversational turns, suggesting that the overall amount of conversation between adults and children in the families was similar across all conditions $X^2(6) = 12.53$, $p = .055$. There were also no differences in amount of conversational turns when looking at the two Sign Up conditions (math specific and general) $X^2(3) = 4.92$, $p = .178$, and between the Sign Up General condition and the No Sign condition $X^2(3) = 3.21$, $p = .360$.

When analyzing differences between conversational turns between the low-SES store and the high-SES store, similar results were also found. Using a Pearson Chi Squared test, we found no significant differences across all three of the conditions $X^2(3) = 1.65$, $p = .649$, as well as no differences in amount of conversational turns when looking at the two Sign Up conditions (math specific and general) $X^2(3) = 3.06$, $p = .382$ and between the Sign Up General condition and the No Sign condition $X^2(3) = 1.12$, $p = .773$.

4.0 DISCUSSION

This study provided data on a cost-effective intervention in a naturalistic context that has the potential to increase conversations between adults and children. Specifically, we were interested in whether or not putting up signs to promote adult-child conversations about math and other topics in a grocery store would increase adult-child conversations, and whether the effectiveness of the intervention would differ as a function of SES. Our overarching aim was to promote adult-child conversations in hopes that this might be a way to boost children's opportunities for learning academically relevant content and ultimately their readiness for school.

We hypothesized that adult-child conversations would be influenced by the presence and types of signs that they encountered. As expected, when signs with math-related prompts were up, math talk in adult-child interactions increased. Previous research has shown that the amount of math talk that children are exposed to from their caregivers is related to children's math abilities (Levine et al., 2010; Elliott, Braham, & Libertus, 2017). Thus, our findings suggest that this low-cost intervention in grocery stores holds the potential for improving children's math abilities. This would be particularly important at a young age because several studies have shown that learning math skills before entering school or while in the very early years of schooling can be positively influential for math skills and achievements in later life (Jordan, Kaplan, Locuniak, & Ramineni, 2007; Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; Siegler et al., 2012). With the cost-effective implementation of signs in a natural environment like the grocery store where families are often together, especially families with young children, adult-child conversations about academic topics could easily increase. Since the age range of children in the study was between 2 and 5 years old, our study begins to try and help bring more math talk to conversations for children in ages before and beginning their school years, which has been shown as a critical period for children's math education.

In addition, there were more math-related adult-child conversations during the math-specific condition in the low-SES store compared to the high-SES store. For example, adults were about 14% more likely to elicit a number word when in the low-SES store compared to the high-SES store. Also, children were about 15% more likely to use a number word when in the low-SES store compared to the high-SES store. Hence, the math-specific signs had more of an impact in the low-SES store when compared to the high-SES store. Given that low-SES children often lag behind their peers from middle and high-SES families in math, this finding is particularly promising as it suggests that SES-related math gaps could be decreased by implementing low-cost interventions such as the one examined here that lead to more opportunities for low-SES children to experience math in a meaningful context.

Improving low-SES children's opportunities for learning math is important because previous research has shown significant gaps between low- and high-SES children in math even before the start of formal schooling (Levine et al., 2010; Jordan et al., 2009; Lee & Burkan, 2002). This lack of academic development could be due to many different factors, but conversations about math in a natural setting could help ameliorate it. Prompting more academic conversations in grocery stores could lead to more conversations at home or places beyond the grocery store, which could lead to better school readiness for children. If children do not have exposure to mathematics, then the gap between children from low-SES and high-SES backgrounds can continue to grow over time and increase disparities. Beginning to close the gap at such an early age is particularly important because the longer they wait, the less prepared for school they will be, and the larger the gap becomes.

When we analyzed data on conversational turns across all three conditions (Sign Up Math, Sign Up General, and No Sign), there were no significant differences for the teachers and the children. The lack of differences in conversational turns shows that parents and children were engaging with the signs equally and that none of the signs were more eye-catching or interesting than others. It can also be concluded that the signs did not increase conversations in general, but rather redirected the topic of conversations. For example, in the Sign Up Math condition, the math signs did not necessarily increase adult-child interaction, but rather focused the conversation on math.

On the one hand, our results contradict those by Ridge and colleagues (2015) because we did not find any increases in conversational turns during the Sign Up conditions (Math and General). This could be due to the sample size of people at each location for each condition and area. On the other hand, our results align with previous research by Ridge and colleagues (2015) who found that conversations about the topics on the signs increased when signs were posted and this was particularly pronounced in low-SES store. We extend these findings by showing that posting math-related signs significantly increased mathematical conversations between adults and children.

Differences between low-SES and high-SES stores in our study as well as the one by Ridge et al. (2015) could be due to a lower base rate of conversations in low-SES families compared to high-SES families (Hart & Risley, 1995). Thus, adults in the low-SES stores may be more sensitive to the content of the signs and use them as a conversation starter compared to adults in the high-SES stores who may already be talking to their children and are not as sensitive to external prompts.

One limitation of this study is that it was only conducted in two store locations; one for low-SES and one for high-SES. Although we did get clear differences between the two locations, our data would have been stronger if there were multiple locations for both high- and low-SES, as well as locations from mid-SES areas. With additional grocery stores, there would be more variety of data and a larger sample size of participants.

Another limitation is that we assume the SES of the families based on the zip code where the store is located, but we are unaware of the exact demographics of shoppers. If specific data were collected to determine true demographics, this could either alter or strengthen the results found for differences between low-SES and high-SES.

A third limitation of the study is that after the families leave the grocery stores, researchers do not have any way of determining whether or not conversations continue in other environments. Due to the nature of our observational studies, we could not inform families that we were watching them and could not get any additional information about what occurs outside of the shopping locations. In order to help with this, further research could break the observational coding and hand out surveys to families when leaving the store, after they were coded, that describe the study and then ask for additional information about adult-child conversations about general language and math talk outside of grocery stores. That could bring in other limitations with self-reports but it would help with knowledge of later conversations for academic achievement. Further research can include more store locations to increase amount of families and change data collections to help understand academic preparation within homes and locations outside of the grocery store setting.

Based on the evidence of increased talk between adults and children, it is necessary to find and implement cost-efficient interventions to support math talk and other academic conversations, especially in low-SES areas. Our research helped to further previous research, but more interventions could be completed to help more families. Our findings should inspire more research to be conducted in similar ways to continue interventions in natural settings for low-SES families. Finally, future research should broaden the types of data that are collected to determine if and how the initial exposure to math-related input in the grocery stores affects interactions elsewhere.

APPENDIX A

CODING MANUAL

Observing Adult-Child Interactions

In the natural supermarket setting, researchers will discreetly observe adult-child interactions. While observing, researchers will act as though they are fellow shoppers while they code. The coding process will be conducted through an online survey application Qualtrics that will be accessed through the researchers' phones. Young adults are commonly on their phone, which helps conceal the coding process. It is extremely important to be close enough to the families being observed in order to hear their conversation.

During observations, if a family has more than one child, researchers will choose one child that is in the age range. If there is more than one child in the age range, researchers will choose the younger child still in the age range and then for subsequent similar families, researchers will choose the older child in the age range. This allows for variation in the ages of the children. Any adult or older sibling in the family with the target child will be coded. In the coding document, all individuals in the family who are older than the targeted child are labeled "teacher(s)." Any random individuals, like other shoppers not part of the family or store managers, should not be included in coding.

Reliability

Before the coding process begins, all researchers will need to be reliable. Researchers will observe in pairs and will code the same adult-child interaction for a total of 5 observations each. Reliability will then be calculated across observations and observers. The goal should be at least 80-85% agreement for all codes. Once reliability across all observers has been reached, coding can begin.

Age, Race/Ethnicity, and Socioeconomic Status

The ages and race/ethnicities will be guessed as well as possible due to the lack of participation contact and information. Children who are approximately ages 2-5 are included in the study.

Socioeconomic status of participants will be determined by the average percent of people with income under the poverty line, based location of the store.

Sign Location and Coding

Before coding, researchers will place themselves within one of three areas of sign locations. Signs will be places in the dairy section near the milk, farther down the dairy section near the eggs, and the bread section near the sliced breads. These areas of coding will be the same for all three conditions. Within each area, all coding should take place in the same general location. For each store visit, one researcher will code in one of the location at a time. It is recommended that researchers code an even amount of families in each section. For example, if a researcher codes 20 families in the bread section, then the next researcher needs to code 20 in the egg section and 20 in the milk section to keep data even for all stores. The same format should be used for the no-sign condition as well. No more than one coder should be in one location at a time to control for repeated families at other sign areas in the same store.

Only families that stop and interact, even briefly, in the area that is being coded, are considered participants. For all three conditions including the no sign condition, you will begin coding near the sign or where the sign will be placed. While coding, researchers can move around in the sign area to better observe the interaction and look more natural. If there is more than one interaction in a particular area, only code the first interaction.

When a family stops in the designated area, the researcher should begin coding the observation on Qualtrics. Observation number, socioeconomic status, condition, and area must be initially recorded before moving on to the observational coding. Once the family is no longer in the designated area, at the end of the survey are the date, time, and general notes. General notes are included to provide additional information that researchers may find important and cannot be communicated through any other code.

Conversational Turns

Conversational turns are verbal exchanges between the children and "teacher(s)" when speech is from the child and the family's speech is directed toward the child. Conversations turns from the child can be any utterance that comes from their mouth and that is coded. Conversations turns from the teacher(s) in the family must directed to the targeted child in order to code them. It can be difficult to determine if speech is directed to the child, so if the child is looking at the speaking "teacher" or they say the child's name in the statement, then it will count. If two "teachers" from the family are talking amongst themselves, without including the child or talking about a topic the child would not understand, that conversation is not counted in the turns. Non-verbal gestures, like heading nodding or shaking, when responding to a statement are counted as conversational turns.

Moreover, conversational turned were often comprised of one or more sentences or speech fragments. Adults and children often said more than one sentence, and even changed topics, within a single conversational turn (e.g., “Teacher” says to the child: “I think we should buy some milk. We could make chocolate milk when we get home since you did so well in school today! Would you want to invite a friend over?”). All of these statements would be counted as one conversations turn from a “teacher” to the child.

Agreeing upon and clarifying with research assistants what will be coded as a conversation turn is critical to ensure reliability of the coding, as well as comparison with similar studies. Conversations turns are coded in a range from 1, 2-5, 6-9, and 10+. It can be challenging to count the *exact* amount of conversational turns so researchers should do their best when observing to count in order to make an accurate estimate of the number of turns.

Who initiated first conversational turn

When the conversation begins, code who started the first conversational turn. If the child is the first to speak, they are automatically the one to start the turn. If one of the “teachers” is the first to speak, they will only be counted for initiation the conversation if their speech is directed to the targeted child. If their speech is directed to someone in the family that is not the targeted child, they are not coded for initiating the first conversational turn.

Product

Points to product

Takes and shows product

Says name of product

Asks question about product

- *"Mom, why is milk white?"*
- *"How is bread made?"*

Describes features of product

- *"This milk is chocolate milk and it is brown, not white."*
- *"This bread has many seeds and grains."*

Gives information or explanation

- *"We drink almond milk so our milk doesn't come from cows, it comes from almonds."*
- *"Bread is made from wheat, and farmers grow wheat on farms."*

Puts product in cart

Off Topic Conversation

Do not stop coding if/when the conversation goes off topic. Conversations naturally go off-topic from the signs. The signs are used as a tool to promote conversation, but other topics such as school or home life should still be included. Until the family is sign area, do not stop coding.

Asks question

- *"How was your day at school today?"*
- *"What do you want to have for dinner tonight?"*

Uses descriptive language:

- *"Your favorite apple is green and sour."*
- *"I like this pink shirt I'm wearing."*

Gives information or explanation:

- *"This cheese is a dairy product and it comes from cows."*
- *"My friend didn't come to school today because she was sick and had a fever."*

Price

Points to price of product

Says price of product

- *"This loaf of bread costs 3 dollars and 30 cents."*
- *"Our milk costs 2 dollars and 75 cents."*

Discusses price of product

- *"This loaf of bread costs 3 dollars and 30 cents, but this loaf of bread costs 2 dollars and 90 cents. The second loaf of bread is cheaper."*
- *"Our milk costs 2 dollars and 75 cents this week, but last week it was 60 cents cheaper."*

Sign

Both examples will be referring to the sign in the egg area, first in the math condition and second in the language condition.

Points to sign

Talks about characters on sign

Reads questions 1

- *"How many eggs are in a carton?"*
- *"What animal lays eggs?"*

Gives answer to question 1

- *"There are 12 eggs in a carton."*
- *"Chickens lay eggs."*

Elaborates on question/answer 1

- *"Sometimes we buy the large carton of eggs which have 18 eggs in them."*
- *"The female chickens lay the eggs and they are also called hens."*

Reads question 2

- *"If we each at an egg, how many would be left?"*
- *"What does the animal look like?"*

Gives answer to question 2

- *"There are two of us, so there would be ten eggs left."*
- *"Chickens are small animals with a beak, feathers, two feet, and wings."*

Elaborates on question/answer 2

- *"If your brother and sister were here then we would eat four eggs, so we would have 8 eggs left."*
- *"Male chickens are called roosters and they are more colorful and make loud sounds."*

Math Specific

Any language the "teacher(s)"/child uses involving or relating to numbers. Specific codes are listed below with examples for each:

Uses a number word

- *"I want one carton of eggs."*
- *"There are twenty-four slices in a loaf of bread."*
- *"Should we get two gallons of milk?"*

Elicits a number word

- *"How many do you want?"*
- *"How many eggs are there?"*

Counts with pointing: Verbal counting with use of any physical gestures, like pointing to objects or counting on fingers.

- *"Let's count together how many pieces of bread there are: 1, 2, 3, 4, 5…"*

Counts without pointing: Verbal counting, like the above example, but without any physical gestures.

Elicits counting

- *"Can you count how many?"*
- *"Count them."*

Performs an operation with gestures: Uses fingers of physical objects to demonstrate arithmetic operation

- *"Twelve minus two is ten."*
- *"One for me, and one for you, so ten eggs would be gone!"*
- *"We would have 9 eggs left!"*
- *"The answer is 7."*

Performs an operation without gestures: Performing arithmetic operations, like the above examples, but without any use of fingers or physical objects to demonstrates

Elicits an operation

- *"If you and I each ate an egg, how many eggs would be gone?"*
- *"How many if you drink one glass a day and there are seven days in a week?"*
- *"Half of twenty-four is what?"*
- *"Twelve minus two is ______?*

Valence

The valence of the interaction refers to the overall feeling/affect of the interaction. Positive affect is seen by a positive tone of voice, smiling, laughing, affection, terms of endearment, and responsive interaction. Negative affect is seen by a cold tone of voice, frowning, scolding, anger/frustration responses towards child, and disengagement. Neutral interactions are neither positive nor negative, but rather lack in emotional expression. This is coded through a likert scale of 1-5, 1 being very negative, 3 being neutral, and 5 being very positive.

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