EXAMINING THE RELATION BETWEEN PARENTAL PRAISE, AFFIRMATION, AND CORRECTIVE FEEDBACK AND PRESCHOOL-AGED CHILDREN'S MATH AND LANGUAGE SKILLS

by

Chelsea E. Carver

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This thesis was presented

by

Chelsea E. Carver

It was defended on

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and approved by

Dr. Elizabeth Gunderson, Associate Professor, Temple University Department of Psychology

Dr. Elizabeth Votruba-Drzal, Professor, University of Pittsburgh Department of Psychology

Dr. Leanne Elliott, Postdoctoral Fellow, University of Pittsburgh Department of Psychology

Thesis Advisor/Dissertation Director: Dr. Melissa Libertus, Associate Professor, University of Pittsburgh Department of Psychology

Examining the Relation Between Parental Praise, Affirmation, and Corrective Feedback and Preschool-Aged Children's Math and Language Skills

Chelsea E. Carver, BPhil

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Prior research has shown associations between parent and teacher feedback and school-aged children's academic outcomes. Specifically, studies have demonstrated that positive feedback (i.e., praise and/or affirmation) is positively related to children's academic outcomes, while negative feedback can be positively or negatively related to children's academic outcomes. Little is known about the relation between domain-general versus domain-specific parental feedback and younger children's academic skills. The present study examines the frequency of positive and negative types of general and math-specific feedback that parents provide their 4-year-old children, and how the frequency of those feedback types relates to children's concurrent math and language skills, as well as their change in math skills over a one-year period. Parent-child dyads (n=91) were observed interacting with a picture book, grocery store set, and magnet board puzzle for 5 to 10 minutes each, after which dyads completed math and language assessments. General affirmation was positively associated and general corrective feedback was negatively associated with children's concurrent math outcomes, while only general corrective feedback was uniquely negatively associated with the same measure. General praise was individually and uniquely positively associated with children's expressive vocabulary and change in math outcomes. However, math-specific feedback was not significantly related to children's math or language outcomes, except for the relation between math-specific corrective feedback and children's concurrent math abilities. This study suggests that the relations between parental feedback and

young children's academic outcomes depend on the type and domain-specificity of the feedback, which can inform how parents provide learning opportunities for their children in the home environment.

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Preface

I would like to give a special thanks to my thesis advisor, Dr. Melissa Libertus, and my graduate mentor, Shirley Duong, for their guidance and support throughout the completion of my thesis. I would also like to express my gratitude to my Bachelor of Philosophy committee members for their feedback and time, as well as to the rest of the Kids' Thinking Lab for their assistance with transcribing and coding.

1.0 Introduction

Many children enter kindergarten with disparities in their knowledge of fundamental math concepts, which negatively impact their ability to learn more advanced material, succeed academically, and thus excel in the workforce (Duncan et al., 2007). This incomplete knowledge base may even prevent children from entering STEM careers that, according to policy makers and educational leaders, are currently experiencing the most growth (Noonan, 2017). Thus, ensuring that children acquire foundational math skills prior to entering formal schooling is critical to maintaining sufficient numbers of STEM professionals to support economic growth and technological advances.

One relevant factor explaining differences in children's early math skills is the verbal input children receive from their parents in the home environment. Prior work has demonstrated that parental feedback is predictive of children's future academic performance with children's mindsets as the mediator (Gunderson, Sorhagen, et al., 2018). People tend to exhibit a coherent set of cognitions, attitudes, and behaviors that align with one of two mindsets (Gunderson et al., 2013). Individuals with a fixed mindset believe their abilities are immutable. They view challenges as tests of whether they inherently possess the desired amount of an ability such that they value performance over learning goals, attribute success and failure to innate abilities, and hold negative beliefs about effort (Mueller & Dweck, 1998).

Alternatively, people with a growth mindset believe their traits are malleable and can be cultivated through effort and generating strategies for improvement (Gunderson et al., 2013). They value learning over performance goals, attribute success and failure to hard work, and hold positive beliefs about effort, resulting in them adopting an adaptive mastery-oriented response to failure.

This includes constant or improved performance, self-instruction and motivation, more positive affect, accurately recalling performance, and high expectations for future performance (Smiley & Dweck, 1994). They view challenges as learning opportunities and seek out experiences that challenge them and improve their abilities further (Mueller & Dweck, 1998).

Past research has indicated that adolescents' mindsets have a lasting impact on their academic achievement: adolescents who held a growth mindset showed an increasing trajectory of math grades while controlling for prior math achievement compared to the flat trajectory of adolescents with a fixed mindset (Blackwell et al., 2007). Thus, it is important to examine how the feedback parents provide in the home environment may impact children's academic skills via their mindsets and result in knowledge gaps prior to formal schooling, since this information can suggest interventions that can be implemented to ensure that the next generation has the STEM knowledge they need to make positive contributions in their chosen fields and to society. The goal of this study was to examine how different forms of parental feedback, specifically parental praise, affirmation, and corrective feedback, are related to children's academic abilities before they enter formal schooling.

1.1 Role of Praise on Child Outcomes

One form of parental input that has been shown to influence children's academic performance via their mindsets is praise (Gunderson et al., 2013). As noted by Henderlong and Lepper (2002), praise has been found to positively influence various outcomes for school-aged children, including self-perceptions of ability, interest in and motivation for completing the praised task, and the development of academic skills. Potential mediating variables for these relations include self-efficacy, perceived competence and autonomy, and positive self-perceptions. Bąk and Leśniak (2020) found that praise following failure resulted in increased self-perceptions of intelligence and affect for high school students. Beneficial effects of praise have also been observed for younger children. Overall, parental praise was shown to positively predict the learning goals of children in first through eighth grade (Gunderson, Donnellan, et al., 2018). Morris and Zentall (2014) demonstrated that verbal and gestural ambiguous praise, which make up the majority of praise children receive, resulted in increased motivation in 5- and 6-year-old children, as indicated by increased persistence, self-evaluations, and reduced fixation on errors following failure.

However, increasing the frequency of praise may only be beneficial to a certain extent. Lee and colleagues (2017) found that parents' praise was only positively related to children's academic achievement when it was perceived as accurately reflecting or slightly overstating their actual performance on schoolwork. Also, Henderlong and Lepper (2002) noted that the beneficial effects of praise are greatest when it promotes autonomy, provides attainable expectations, and improves children's abilities without relying heavily on social comparisons.

There are two main types of praise that correspond with the two mindsets. Person praise (e.g., "you're so smart" or "you're so good at this") commends the child's abilities based on their performance, implying their abilities are inherent and stable. This global assessment suggests their performance is reflective of their competence or worth, fostering contingent self-worth and a fixed mindset (Kamins & Dweck, 1999). In contrast, process praise (e.g., "you tried hard" or "good job") commends the child's effort or strategies in one specific episode, which implies their abilities are malleable and leads to them adopting a growth mindset. All other praise utterances that do not explicitly target the child's efforts or inherent qualities are considered "other praise."

Person praise following children's success has repeatedly been shown to have many negative effects, particularly for children with low self-esteem (Brummelman et al., 2016). After receiving person praise, children may interpret their performance as indicative of ability and develop ability attributions for successes and failures, increasing their vulnerability to a helpless response to failure and performance goal orientation (Diener & Dweck, 1978; Elliott & Dweck, 1988; Kamins & Dweck, 1999). Pomerantz and Kempner (2013) found that academically relevant parental person praise in response to 10-year-old children's academic success predicted children's fixed mindsets. However, Gunderson and colleagues (2013) did not find a significant relation between parental person praise bestowed in non-academic contexts and 7- to 8-year-old children's adoption of a fixed mindset, which suggests that person praise may be more salient and impactful at a later age and/or in more academically relevant settings.

In contrast, process praise has been found to have a multitude of positive effects. This includes children adopting a learning goal orientation, focusing on mastering new material to improve their skills, seeking challenges, and exhibiting enhanced achievement motivation, persistence, positive affect, and performance in the face of difficulty (Dweck & Leggett, 1988; Nicholls, 1984). Parental process praise bestowed upon children at 1 to 3 years in the home environment positively predicted their math and reading achievement at 9 to 10 years, with children's growth mindsets at 7 to 8 years as a mediator (Gunderson, Sorhagen, et al., 2018). The relations remained significant when overall parent talk, SES, child gender, and academic achievement at 7 to 8 years were controlled for, which suggests that parental process praise results in the improvement of children's academic abilities over time. However, Amemiya and Wang (2018) noted process praise can backfire in adolescents due to their perception of process praise as implying they need to exert effort due to low innate ability.

Children have demonstrated susceptibility to the implications of person praise versus process praise as early as kindergarten. Children ages five to six who received consistent process praise exhibited greater self-assessments, persistence, motivation, and positive affect following failure compared to those who received consistent person praise, which are all characteristic of a growth mindset (Kamins & Dweck, 1999). Cimpian and colleagues (2007) showed that the difference in connotation between the two praise types can even impact achievement motivation and response to failure in preschoolers. Despite this significant body of research on parental praise, research has yet to examine how parental praise in the home impacts young children's academic outcomes prior to formal schooling. Therefore, this was examined in the current study.

1.2 Role of Affirmation on Child Outcomes

In addition to praise, other more generalized forms of positive parental feedback such as affirmation have been shown to impact children's academic achievement. Unlike praise, which conveys positive affect and emphasizes the child's behavior or abilities, affirmation (e.g., "that's correct" or "yeah") conveys the correctness or comprehension of the child's response (Reigel, 2008). Prior research showed that teacher affirmation following correct responses was significantly related to standardized test scores of fourth- and fifth-grade minority students (Buriel, 1983). However, teacher affirmation may be contingent upon student academic achievement, since high achievers received more affirmation. A study with ESL students found similar results: increased teacher positive feedback, including affirmation and praise, was associated with improved performance on informal classroom assessments, posttest performance, and motivation to pursue a higher level of learning (Reigel, 2008). Similarly, Morris and Zentall (2014) demonstrated that verbal ambiguous praise, an utterance category that was defined as affirmation in this study, bestowed upon kindergarteners was equally or more motivating than process praise. These studies suggest that many forms of positive feedback, including praise and affirmation, can impact children's academic outcomes.

Additionally, Buriel and Reigel (1983; 2008) observed a higher frequency of affirmation relative to praise, so affirmation was likely the most salient form of reinforcement that students received. This finding is supported by a functional analysis of teacher praise (Brophy, 1981), which found that teacher praise was sporadic, global rather than specific, and not contingent on performance. Reigel (2008) also noted that authentic positive feedback, including praise and affirmation, is more likely to benefit children than forced or contingent praise with the aim of improving academic outcomes. This may also hold true for parent-child dyads, so it is important to examine how parental affirmation in the home impacts young children's academic skills prior to formal schooling.

Notably, prior research varies on the types of utterances that are considered affirmation. Gunderson and colleagues (2013) defined affirmation as a sub-category of other praise, which includes utterances that affirm the child's response and occur in a praise context, like "you're right" and "you did it," while excluding more objective utterances that occur in a non-praise context and could be perceived as simple commentary on the child's response, like "yes" or "you are buttoning it." In contrast, Reigel (2008) defined affirmation as distinct from praise and consisting of more objective utterances like "yeah" and "okay." The varied definitions of affirmation from prior research were considered and incorporated when defining affirmation in the current study.

1.3 Role of Corrective Feedback on Child Outcomes

In addition to positive feedback, negative feedback has been shown to impact children's response to setbacks and thus their future performance (Kamins & Dweck, 1999). On the one hand, some motivation theories argue negative feedback is more effective for motivating goal pursuit than positive feedback because negative feedback in response to an individual's lack of success can suggest more effort is needed for goal attainment and thus encourage goal pursuit, while positive feedback can suggest partial goal attainment and result in reduced effort toward goal attainment (Fishbach et al., 2010). Negative feedback can draw the learner's attention to errors in their performance and prompt modifications to their previous utterances or behaviors, providing a learning opportunity and positively impacting their academic development (McDonough, 2005).

On the other hand, there are also motivation theories that posit positive feedback may be more effective because it increases people's confidence in their ability to pursue goals, resulting in increased expectancy of successful goal attainment, while negative feedback undermines people's confidence and outcome expectancy (Fishbach et al., 2010). According to cognitive evaluation theory, negative feedback results in reduced self-evaluations of competence and intrinsic motivation, fostering a fixed mindset (Gunderson, Donnellan, et al., 2018). For instance, greater teacher criticism in the academic domain was negatively correlated with fourth- and fifth-grade students' standardized test scores (Buriel, 1983), and greater parental criticism predicted maladaptive perfectionist outcomes in high school students that were associated with a performance-avoidance goal orientation (Madjar et al., 2015). However, research has yet to examine whether parental criticism in the home is positively or negatively associated with young children's academic outcomes prior to formal schooling.

As noted by Schachter (1991), children develop the ability to utilize negative feedback between the ages of 5 and 9 years. Despite this development, Schachter also noted that children between the ages of 4 and 9 years often do not respond to negative feedback and instead hold on to their original incorrect hypotheses, which could lead to more negative parental feedback on the same subject. Nguyen and Lwin (2014) found that 3- and 4-year-old English-speaking Singaporean children did not adjust their behavior after parental corrective feedback 67% of the time during dyadic interactions. These two studies suggest that on average children do not acquire the ability to uptake and internalize negative feedback in a way that leads to a change in their response until the age when formal schooling begins. The present study aimed to examine whether children respond to corrective feedback at an earlier age prior to formal schooling in a way that impacts their academic abilities.

In addition, it is important to examine the relative impact of parental positive feedback and negative feedback in the home environment on the same children's academic outcomes. Dorrington and van Nieuwerburgh (2015) reported that 10- to 11-year-old English children were more likely to respond to negative feedback when it was preceded by positive feedback, indicating their greater relative receptiveness to positive feedback. Similarly, Berkeljon and Raijmakers (2007) found that for Dutch children as young as 4 years old, negative feedback had a lesser impact on their neural networks, which model discrimination learning processes, compared to the neural networks of adults. Furthermore, van Duijvenvoorde and colleagues (2008) found greater activation in brain areas sensitive to the presentation of negative feedback and the need for response adjustment in 11- to 13-year-old children compared to 8- to 9-year-old children, indicating that children develop this sensitivity between 9 and 11 years of age. In addition, they found that brain areas sensitive to the informative value of feedback were more responsive to negative feedback for adults, while 8- to 9-year-old children demonstrated greater sensitivity to positive feedback and 11- to 13-year-olds did not exhibit differential feedback sensitivity. This suggests that at the age of 4 years old, children may be able to comprehend and learn from positive feedback but not corrective feedback. Four-year-old children's differential sensitivity to positive feedback and negative feedback was examined in the present study.

1.4 Children's Math Achievement

Individual differences in knowledge of fundamental math concepts are present by the time children enter preschool as indicated by standardized math test scores (Starkey et al., 2004). Children's math knowledge upon entering formal schooling has been shown to predict later math achievement (Duncan et al., 2007). One contributing factor may be the variation in parental math talk children are exposed to in the home from a young age (Levine et al., 2010). In support of this concept, caregivers' engagement in number-related activities with their preschool-aged children in the home predicted foundational number skills like counting, and caregivers' advanced number talk predicted advanced number skills like cardinality (Ramani et al., 2015). A study with 3-year-old children demonstrated analogous results: maternal support of children's numerical concepts learning predicted preschool and first-grade math outcomes (Casey et al., 2018). Maternal support of children's spatial concepts learning and planning was found to have similar positive benefits (Lombardi et al., 2017).

Prior work has revealed that young children are susceptible to math-specific verbal input, as two different studies showed that children in preschool through second grade exhibited changes in math performance following activation of math-specific stereotypes (Ambady et al., 2001;

Beilock et al., 2010). This suggests that upon receiving math-specific feedback, children would recognize the feedback as an opportunity to internalize their math-specific strengths or weaknesses in a way that impacts their math-specific academic abilities. In addition, Dweck (2008) noted that children tend to hold a more fixed perspective of math skills compared to other academic skills. In support of this finding, a study by Gunderson and colleagues (2017) found that children in first and second grade reported that success in the workforce requires more fixed ability in math than in other domains such as reading and writing. This study also showed that high school and college students' math-specific theories of intelligence predicted their math-specific motivations and achievement, while this was not the case for their reading-specific and writing-specific theories of intelligence. These results indicate that the relation between children's mindsets and their academic achievement can differ for the domain of math compared to other academic domains, thus indicating the importance of examining the influence of math-specific parental feedback on children's academic achievement via their mindsets.

Alternatively, 4-year-old children may not be very sensitive to the domain specificity of the feedback they receive and instead may generalize from feedback. For instance, children may receive domain-general corrective feedback and practice their math-specific skills to correct their initial response such that when they are given a math-specific prompt in the future they can apply that same strategy to correctly answer the question. This concept is supported by the finding that domain-general and math-specific interventions improved the number knowledge of 5- to 7-year-old children (Ramani et al., 2017). Additionally, prior research has indicated that children utilize math-specific and domain-general skills while learning higher-level math concepts (Bull & Lee, 2014; Schneider et al., 2017). Children likely use their domain-general skills to learn initial foundational math skills and then use both sets of skills as a foundation to learn progressively more challenging math skills (Zhang et al., 2017). This suggests that both math-specific and domain-general parental feedback may contribute to children's math abilities, although the relative contributions may differ. Thus, both domain-general and math-specific parental feedback were examined in this study to determine whether any observed relations for general parental feedback could be attributed to math-specific parental feedback.

Interestingly, children's math knowledge upon entering formal schooling has also been shown to impact children's later reading achievement. Duncan and colleagues (2007) found that early math skills and early reading skills had equal predictive power for later reading achievement. Additionally, maternal support of 3-year-old children's spatial concept planning during a block building activity, including maternal efforts to help their children identify and link together incremental steps to reach the block building goal, was shown to be predictive of preschool reading achievement (Lombardi et al., 2017). These results suggest parents' math-specific feedback may impact both children's math outcomes and language outcomes. Purpura and colleagues (2019) suggested that this may stem from broad relations between math and reading since certain aspects of math and reading depend on each other, such as children's dependance on knowledge of written language to understand written mathematical quantities and on oral language ability to verbally represent mathematical quantities. However, they also noted that math and reading both depend on the same general academic skills, such as working memory and executive functioning.

To date, no studies have examined whether domain-specific parental feedback is related to young children's academic outcomes in the same domain prior to formal schooling. In addition to math skills, children's language skills were assessed as a comparison domain to ascertain whether any observed relations between parent input and children's math skills were domain-specific or reflective of general academic abilities.

1.5 The Current Study

This study explored how parental feedback impacts young children's academic abilities. Prior research has examined how parental praise, affirmation, and/or corrective feedback relate to older children's general academic outcomes. However, research has yet to focus on how parental praise, affirmation, and corrective feedback in the home environment impact children's academic abilities before they enter formal schooling. Also, research has yet to examine how domain-specific parental praise, affirmation, and corrective feedback relate to children's domain-specific academic abilities. Specifically, this study focused on the role of math-specific parental feedback on preschool-aged children's math skills. In addition, observational methods were utilized to measure the frequency of parental feedback that children were exposed to in the home environment, which is another dimension on which this study differs from most prior studies. This study addressed three specific research questions (RQ):

Research Question #1 (RQ1): What is the frequency of general and math-specific parental praise (process, person, and other praise), affirmation in a non-praise context, and corrective feedback (process, person, and other corrective feedback) directed at 4-year-old children across three semi-structured observational tasks?

Research Question #2 (RQ2): How are general and math-specific parental praise, affirmation in a non-praise context, and corrective feedback each individually related to children's performance on math and language assessments concurrently and their change in math performance over a one-year period?

Research Question #3 (RQ3): Are general and math-specific parental praise, affirmation in a non-praise context, and/or corrective feedback *unique predictors* of children's performance on math and language assessments concurrently and/or their change in math performance over a one-year period?

2.0 Method

2.1 Participants

The data for this study came from the Parents Promoting Early Learning study currently being conducted at the University of Pittsburgh. The overarching goal of this study is to understand how parents help their preschool-aged children learn and develop through everyday home learning activities. Initially, 128 participants were recruited to take part in this study when children were 4 years old. Dyads were invited for a follow-up about a year later when children were 5 years old. However, 37 participants did not complete all relevant measures for purposes of the current study and/or had corrupted video files and were therefore excluded from the study. Thus, the final sample for the current study consisted of 91 four-year-old children (*M* child age at the time of the first wave of data collection=4.41 years, *SD*=0.30 years, 49.45% male, 50.55% female) and one of their primary caregivers (95.45% mothers, 4.55% fathers) from the greater Pittsburgh, Pennsylvania area. The average delay between the first and second wave of data collection was 1.07 years (*SD*=0.12 years). Based on available caregiver self-reports, 84% identified as White Non-Hispanic, 9% identified as Black, 3% identified as Asian, 2% identified as Hispanic/Latino, and the last 2% identified as Other/Multiracial. On average, caregivers were highly educated, with the majority possessing at least a Bachelor's degree (82.23%) and the remainder having obtained a limited college education that was insufficient to earn a degree (6.67%), an Associate's degree (3.33%), a high school diploma (4.44%), or training from a vocational/technical program (3.33%). Parents' average annual reported household income was $109,816.90 (*SD*=$69,921.24, median=$100,000, range=$5,000-$350,000). In compliance with the local Institutional Review

Board, all caregivers provided written consent to participate prior to engaging in any research-related activities.

Given that the subsample of excluded dyads was much smaller than the included subsample, Welch's *t*-tests were used to determine whether the excluded and included groups differed significantly on the child outcome variables, child age, and demographic variables (annual reported household income and years of parental education). The excluded and included subsamples differed significantly on expressive vocabulary and annual reported household income. The excluded subsample exhibited considerably lower Developmental Vocabulary Assessment for Parents (DVAP) scores than the included subsample, $t(126)=7.47$, $p<.001$, with an average score of 108.54 out of 212 words ($SD=26.75$) for the included subsample and 53.68 ($SD=56.33$) for the excluded subsample. The excluded subsample also reported fewer years of parental education than the included subsample, $t(126)=3.25$, $p<.001$, with an average of 16.44 years ($SD=1.90$ years) for the included subsample and 15.14 years ($SD=2.41$ years) for the excluded subsample. The two subsamples did not significantly differ on the other measures.

2.2 Measures

2.2.1 Semi-Structured Interactions

To obtain an estimate of how much parental feedback each child received, researchers video-recorded parent-child dyads as they engaged in three different semi-structured tasks designed to stimulate a broad range of conversations between the parent and child. Although much prior research has utilized parents' self-report measures of positive and negative feedback bestowed upon their children during home activities, these measures have been shown to inaccurately represent actual parent feedback (Swenson et al., 2016). Thus, semi-structured tasks that resemble potential day-to-day activities for the dyads were utilized instead. A total of 90 dyads completed these tasks in the home, while one dyad completed the tasks in the lab.

The first task involved sharing a picture book created by the research team that did not contain any text but still provided opportunities for math-related talk about counting, calculation, and spatial relations. The second task involved a magnet board puzzle consisting of magnetized shapes and a picture prompt. The third task involved a grocery store set consisting of a cash register and plastic food items. For all tasks, parents were encouraged to play with their child as they normally would with the respective toy, and for the magnet task parents and children were given additional instruction to use the magnetized shapes to construct a giraffe as depicted in the picture prompt. Dyads spent around 5 to 10 minutes on each task, during which the researchers stepped out of the room to facilitate naturalistic play.

The entire dialogue for each video was transcribed verbatim at the utterance level by trained research assistants in the lab using Datavyu, an open-source behavioral coding software (Datavyu Team, 2014). An utterance was defined as a unit of speech separated by grammatical closure, intonation contour, or prolonged pausing at the end of a complete thought or sentence (Gunderson, Sorhagen, et al., 2018; Rowe et al., 2004). All transcripts were checked by a second trained research assistant from the lab for reliability. The checked transcripts were subsequently coded for instances of praise, affirmation, and corrective feedback.

Praise referred to any utterance that provided positive feedback or reinforcement in response to the child’s verbalizations, actions, and/or product of their actions and contained an explicit or implicit positive valence (Gunderson et al., 2013; Reigel, 2008). Consistent with the coding scheme developed by Gunderson and colleagues (2013), praise was further broken down into three different categories: (1) Person praise consisted of utterances that implied the child possessed a fixed, positive quality. This included utterances that provided a label for the child without the use of a verb (e.g., “good boy”) or described the child using a copular verb (e.g., “you’re so smart”). (2) Process praise consisted of utterances that emphasized the child’s decisions, effort, actions, or strategies with respect to the task (e.g., “good job”). (3) All other praise responses that did not fall into the other two categories were considered other praise. This included praise that expressed a general positive valence but lacked explicitness about whether the target of the praise was the child’s personal traits or process (e.g., “very good”), praise that emphasized the product or outcome of the child’s actions (e.g., “nice puzzle”), and affirmation in a praise context, which was initially coded separately from other praise and was later combined with other praise for data analysis. Examples of each praise category are provided in Table 1.

A script was used to search the checked transcripts for a specified set of words commonly found in praise utterances (good, job, high, five, there, we, go, totally, wow, had, right, here, very, looks, great, nice, cool, give, up, awesome, got, did, own, yourself, perfect, amazing, beautiful, impress, excel, wonderful, ace, like, love, smart, idea, found, girl, boy, correct, yay). Then, each selected utterance was assessed to determine if praise had occurred, since the script often selected utterances that included search terms but were not instances of praise, and if so which category of praise. Each utterance was coded with only one praise category. Also, the checked transcripts were manually searched to see if the script missed any instances of praise.

Affirmation referred to any utterance that confirmed and therefore conveyed the correctness or comprehension of the child’s verbalizations, actions, and/or product of their actions (Reigel, 2008). Based on the aforementioned coding scheme by Gunderson and colleagues (2013), affirmation was further broken down into two different categories: (1) Affirmation in a praise context consisted of utterances that affirmed the child's response with an implicit statement of positive valence (e.g., "you got it"), and was therefore considered a sub-category of other praise. (2) Affirmation in a non-praise context consisted of all other affirmation responses that were more objective (e.g., "yeah"). This included exactly repeating the child's verbalizations or describing the child's actions that were in response to a parental prompt or question. Examples of both affirmation categories are provided in Table 1.

A script was used to search the checked transcripts for a specified set of words commonly found in affirmation utterances (yes, yea, okay, right, correct, true). Then, each selected utterance was assessed to determine if affirmation had occurred, since the script often selected utterances that included search terms but were not instances of affirmation such as the parent saying "yes" in response to the child's yes/no question (Reigel, 2008), and if so which category of affirmation. Additionally, the checked transcripts were manually searched to see if the script missed any instances of affirmation.

Corrective feedback referred to any utterance that conveyed a negative evaluation of the child's incorrect verbalizations, actions, and/or product of their actions and contained an explicit correction or an implicit negative valence (Kamins & Dweck, 1999). Corrective feedback was further broken down into the same three categories as praise: (1) Person corrective feedback consisted of utterances that implied the child possessed a fixed, negative quality. This included utterances that described the child using a copular verb (e.g., "you're not very good at this"). (2) Process corrective feedback consisted of utterances that emphasized the child's decisions (e.g., regarding shape selection or placement in the magnet puzzle task) or the child's effort, actions, or strategies with respect to the task. This included utterances that contained an action verb (e.g., "keep turning"), referred to the child's physical manipulation of objects (e.g., the placement of a shape in the puzzle task), or referred to the child's use of a mental process (e.g., performing arithmetic in the book task). (3) All other corrective feedback responses that did not fall into the other two categories due to lack of explicitness about whether the target of the corrective feedback was the child's personal traits or process but nevertheless prompted the child to think about their mistake and/or how to rectify their mistake were considered other corrective feedback. This included feedback that critiqued the product of a child's action (e.g., "that doesn't look right"), critiqued the child's actions or product of their actions with an implicit statement of negative valence (e.g., "not quite"), or disagreed with the child's verbalizations often by adding "no" or "not" to the child's response. Examples of each corrective feedback category are provided in Table 2.

The checked transcripts were manually searched for corrective feedback utterances and each corrective feedback utterance was coded according to which category of corrective feedback had occurred. Each utterance was coded with only one corrective feedback category.

Lastly, coders examined the utterances preceding each coded instance of parent feedback and determined if the feedback was directed at math-specific talk. Generally, math-specific talk took the form of the parent trying to elicit a math-specific response from the child. Math-specific talk was further broken down into two main categories: number talk and spatial talk.

Number talk referred to conversations about number concepts, such as identifying numerals, counting, and arithmetic. Number talk consisted of three types of words: number words, ordinal words, or elicitations. Number words described a discrete quantity of objects (e.g., "there is one we are missing") and were not considered number talk if they were used in a non-numeric sense (e.g., "one" when it can be replaced with the word "thing" or "person", such as "no one is here”). Ordinal words described orders or repetitions that had to explicitly refer to numbers or quantities (e.g., “the first number is one”) as opposed to events (e.g., “I want to go first). Elicitations were words or phrases that elicited number talk or conversations about math, including arithmetic, counting, or stating the amount of something (e.g., “these animals plus two more”), and were not considered number talk if they were referring to a non-mathematical expression (e.g., “I think we played with the blocks enough, plus I wanted to check out this book). This coding scheme was adapted from Levine and colleagues (2010) and Ramani and colleagues (2015).

Spatial talk referred to words that describe the features and location of two-dimensional or three-dimensional objects and spaces. This included words that describe spatial dimensions (e.g., size, length, volume), spatial features and properties (e.g., “side”, “round”, “angle”, “flat”), shapes (e.g., “semicircle”, “rectangle”, “zigzag”), locations/directions/orientations (e.g., “left”, “above”, “next to”, “middle”), continuous amounts (e.g., “whole”, “piece”, “half”, “space”), and deictics (e.g., “here”, “there”). If spatial words were used in a non-spatial context, they were not considered spatial talk. This included spatial words as part of homonyms or diminutives (e.g., “that is the right answer”), metaphors (e.g., “that took a long time”), spatial words that refer to abstract phenomena in two-dimensional or three-dimensional space (e.g., “he’s your little brother”), spatial words used as nominatives (e.g., “sit on your bottom), prepositions (e.g., “he came on foot”), and spatial words used as quantifiers of non-spatial dimensions (e.g., “tell me more”). This coding scheme was adapted from Cannon and colleagues (2007).

In addition, parental feedback in response to the child’s nonverbal placement or movement of a piece in the magnet task was coded as spatial talk. This was included because parents often provided a spatial prompt about the location of a piece that preceded and motivated children’s nonverbal responses, so this allowed for parental feedback to children’s nonverbal or verbal responses to be captured. In contrast, children's responses to parental number or spatial prompts in the other two tasks as well as to other parental math-specific prompts in the magnet task were primarily verbal, so parental feedback was primarily bestowed following children's verbal responses.

Trained research assistants in the lab used scripts to search the checked transcripts for specified sets of words commonly found in utterances that involve number talk or spatial talk. They then assessed each utterance to determine if number talk and/or spatial talk had occurred and if so which categories of number talk and/or spatial talk. Each utterance containing number talk was coded with only one category, while each utterance containing spatial talk was coded with all categories that were identified in that utterance.

Coders determined if the utterances preceding each coded instance of parental feedback were coded as number talk, spatial talk, or both. Specifically, coders examined the prior utterances in the same conversation segment as the current instance of parental feedback that reference the same topic. For this study, a conversation segment typically consisted of a parent's question, the child's response, and the parent's follow-up feedback. Coders identified the exact number talk and/or spatial talk category codes for the preceding utterances. Examples of the three categories of math-specific talk for this study are provided in Table 3.

One coder (the author) reviewed all checked transcripts for instances of parental feedback. Three coders (including the author) identified whether parental feedback occurred in response to math-specific talk. Lastly, 10% of all videos were double-coded and kappa coefficients were calculated to determine the degree of agreement between coders in identifying general and math-specific praise, affirmation, and corrective feedback out of total utterances. Coders were highly reliable in identifying instances of general praise (percent agreement [PA]=.99, κ=.94), person praise (κ=.92), process praise (κ=.92), other praise (including affirmation in a praise context, κ=.93), and math-specific praise (κ=.87). Also, coders were in high agreement for identifying occurrences of general affirmation in a non-praise context (PA=.99, κ=.87) and math-specific affirmation in a non-praise context (κ=.82). Finally, coders were highly reliable in coding instances of general corrective feedback (PA=.99, κ=.89), process corrective feedback (κ=.90), other corrective feedback (κ=.79), and math-specific corrective feedback (κ=.87). Person corrective feedback did not occur in this sample.

2.2.2 Child Math Assessment

After the semi-structured observations, children's math competency was assessed using the Applied Problems subtest of the Woodcock-Johnson Tests of Achievement III, a standardized math test that evaluates children's ability to analyze and solve math problems (Woodcock et al., 2001). The problems become progressively more difficult, with initial items requiring the application of basic number concepts, such as counting (e.g., "How many ducks are in the pond?"), and later items requiring arithmetic (e.g., "If I took away three crayons, how many crayons would I have left?") and knowledge of units, such as currency, temperature, and time (e.g., "Point to the quarter."). Standardized scores were calculated based on the child's age at the time of assessment. Past work has demonstrated high test-retest reliability for this scale in the norming sample ($r(89)$=.93) and concurrent validity with other math assessments (Woodcock et al., 2001).

This test was utilized for the 4-year-old and 5-year-old waves of data collection. Regarding the 4-year-old time point, the assessment was administered to each child during one in-person testing session in conjunction with other assessments of children's math skills that tap into children's number knowledge. The session took place in a quiet room at the child's home immediately after the observational tasks on the same day or at the child's preschool or daycare on a later day. All assessments were administered in the same order by one of five trained graduate students or full-time research staff. For the 5-year-old time point, the assessment was administered to the same children via Zoom due to the COVID-19 pandemic.

2.2.3 Child Language Assessment

Children's language competency was assessed using the Developmental Vocabulary Assessment for Parents (DVAP), an expressive vocabulary assessment in which parents are asked to report which words they have heard their 2- to 7-year-old child say from a list of 212 words taken from the Peabody Picture Vocabulary Test (PPVT-4) (Dunn & Dunn, 2007; Libertus et al., 2015). The PPVT-4 is a widely used experimenter-administered test of receptive vocabulary that serves as a direct measure of children's language abilities in which the experimenter asks children to point to the image that best corresponds to a spoken word out of an array of images (Dunn & Dunn, 2007). The DVAP was utilized in lieu of a child assessment because the DVAP is highly correlated with the PPVT-4, indicating caregiver reports are a reliable measure of children's vocabulary size in early childhood. Past work has demonstrated the concurrent and predictive validity of this assessment (Libertus et al., 2015). This measure was used for the 4-year-old wave of data collection and was administered to parents as part of an online Qualtrics Parent Questionnaire. This test was omitted from the 5-year-old wave of data collection and since no comparable language measures were collected, language skills were not used as a comparison domain for the longitudinal regression models.

3.0 Analytic Plan

To address RQ1, descriptive statistics were examined for the three sub-types of parental praise, parental affirmation in a non-praise context, and three sub-types of parental corrective feedback collapsed across the three semi-structured tasks. All three tasks offered parents the opportunity to provide their children with verbal feedback, so collapsing across tasks allowed for a more comprehensive and representative measure of parent-child interactions in the home learning environment. The descriptive statistics for the math-specific forms of these categories of parental feedback were also assessed to see if the relative frequencies of the different parental feedback types varied depending on whether they were math-specific or not.

To address RQ2, separate linear regression models were utilized to examine the relation between each type of general parental feedback and children's concurrent performance on the math assessment, as well as their longitudinal change in performance. Similar regression models were estimated to examine the relation between math-specific parental feedback and children's math outcomes. To determine whether any observed relations between parent feedback and children's math outcomes were domain-specific or reflective of general academic abilities, all models predicting 4-year-old children's concurrent performance on the math assessment were followed up with parallel models predicting 4-year-old children's concurrent performance on the language assessment.

All regression models included two covariates: parents' overall amount of talk and child age. Parents who converse more with their children have more opportunities to bestow praise, affirmation, and/or corrective feedback (Gunderson, Sorhagen, et al., 2018). To control for children's overall language exposure, the total number of parent utterances for each video was calculated and summed across all three tasks. Moreover, older children have a higher level of expertise and thus likely interact more readily with their parents and perform better during the activity. As a result, parents could bestow more feedback (Uscianowski et al., 2020). Alternatively, since not as much encouragement is needed for older children to complete the task, parents could decrease their feedback. Along the same line, younger children may be less equipped to respond to parents' verbal prompts correctly or appropriately, resulting in parents providing more feedback. In addition, younger children may not make causal attributions about achievement based on the type of parental feedback they receive and thus may not respond to the different categories of parental feedback in the same way as older children (Henderlong Corpus & Lepper, 2007). Lastly, older children may have been exposed to more parental prompts in the home environment that stimulated their development of math and language skills and thus may have higher math and language abilities. As such, the child's age during the semi-structured observations was also used as a control.

The distributions of the different sub-types of parent feedback (person praise, process praise, other praise, etc.) were examined to determine whether to include the sub-types in the regression models. If specific sub-types of feedback had not been normally distributed (i.e., skewness greater than 3 or less than -3 and kurtosis greater than 10 or less than -10), then the sub-types would have been combined (Kline, 2011). For example, if person, process, and/or other praise had not been normally distributed, then all three praise sub-types would have been combined and only total praise would have been utilized in subsequent regression models. The same approach was taken for corrective feedback. Further, if praise had occurred too infrequently or had not been normally distributed, then praise and affirmation would have been collapsed into a composite measure of positive feedback.

To examine RQ3, all categories of general parental feedback were examined in the same linear regression model to determine whether they differentially related to children's concurrent performance on the math assessment, as well as their longitudinal change in performance on the assessment over a one-year period. Additional models were created for math-specific parental feedback. For all models predicting 4-year-old children's concurrent math outcomes, similar regression models were estimated to examine the role of parental feedback for 4-year-old children's concurrent language outcomes. All regression models included the same two covariates of parents' total number of utterances and child age.

4.0 Results

4.1 RQ1: Frequency of General and Math-Specific Parental Praise, Affirmation, and Corrective Feedback

Substantial variability was observed in the frequency of parents' feedback when interacting with their children. Parents produced between 45 and 256 total feedback utterances (*M*=140.97, *SD*=48.48) across the three tasks. Table 4 displays descriptive statistics of parental feedback frequency across all types and tasks and Table 5 displays skew and kurtosis values for parental feedback across all types and tasks. Across all types of parental feedback, parents provided affirmation in a non-praise context with the greatest frequency (*M*=81.41, *SD*=32.44), and bestowed corrective feedback (*M*=35.11, *SD*=19.42) with a greater frequency compared to praise (*M*=24.45, *SD*=13.41). Across praise sub-types, parents provided other praise with the greatest frequency (*M*=18.60, *SD*=11.17) while there was an extremely low frequency of person praise (*M*=0.69, *SD*=1.28). Across corrective feedback sub-types, parents provided the greatest frequency of process corrective feedback (*M*=22.22, *SD*=13.31), while there was an extremely low frequency of person corrective feedback (M=0.05, SD=0.27). Thus, praise and corrective feedback were collapsed across all three sub-types (person, process, and other) for subsequent analyses.

Regarding math-specific feedback, parents produced between 5 and 161 total utterances (*M*=53.92, *SD*=36.91) across the three tasks. Table 6 displays descriptive statistics of math-specific parental feedback frequency across all types and tasks and Table 7 displays skew and kurtosis values for math-specific parental feedback across all types and tasks. Across all types of math-specific parental feedback, parents provided affirmation in a non-praise context (*M*=25.03, *SD*=19.39) and corrective feedback (*M*=20.64, *SD*=14.91) with a similar frequency, which was greater than the frequency with which they bestowed praise (*M*=8.25, *SD*=9.10). The relative frequencies of the different praise sub-types and corrective feedback sub-types were similar for general and math-specific feedback: parents provided other praise (*M*=6.33, *SD*=6.96) and process corrective feedback (*M*=15.88, *SD*=11.37) with the greatest frequency while providing a low frequency of person praise (*M*=0.19, *SD*=0.67) and no person corrective feedback. Akin to general parental feedback, math-specific praise and corrective feedback were collapsed across all three sub-types (person, process, and other) for subsequent analyses.

4.2 RQ2A: Relations Between Each Type of Parental Feedback and 4-Year-Old Children's Concurrent Math and Language Skills

Table 8 displays descriptive statistics of child outcomes and covariates. Children's average Woodcock-Johnson Applied Problems subtest raw score increased from the 4-year-old time point (M=15.30; SD=3.98) to the 5-year-old time point (M=17.30; SD=5.96). The average score on the DVAP at the 4-year-old time point was 108.54 out of 212 words (SD=26.75).

Table 9 displays correlations between general parental feedback types, child outcomes, and covariates, while Table 10 displays correlations for math-specific parental feedback. Among the different types of general parental feedback, the two categories of positive parental feedback, parental praise and parental affirmation in a non-praise context, were significantly positively correlated ($r(89)=.48$, $p<.001$) in that parents who bestowed more praise to their 4-year-old children also tended to bestow more affirmation in a non-praise context. General parental praise was significantly positively correlated with children's DVAP scores at the 4-year-old time point ($r(89)=.26$, $p<.05$), indicating that parents who bestowed a greater frequency of praise tended to have children who exhibited greater expressive vocabulary. General parental corrective feedback was significantly negatively correlated with children's Woodcock-Johnson Applied Problem subtest scores at the 4-year-old time point ($r(89)=-.35$, $p<.001$) and the 5-year-old time point ($r(89)=-.26$, $p<.05$), demonstrating that parents who bestowed a greater frequency of corrective feedback tended to have children who exhibited lower scores on the math assessment concurrently and over time.

For math-specific parental feedback, all three categories of feedback were significantly positively correlated with each other ($p<.001$), meaning that parents who bestowed more of one type of feedback also tended to bestow more of the other two types of feedback. Math-specific parental praise was marginally significantly negatively correlated with children's Woodcock-Johnson Applied Problem subtest scores at the 4-year-old time point ($r(89)=-.21$, $p<.06$), indicating that parents who bestowed a greater frequency of math-specific praise tended to have children who exhibited lower concurrent performance on the math assessment. Math-specific parental corrective feedback was significantly negatively correlated with children's Woodcock-Johnson Applied Problem subtest scores at the 4-year-old time point ($r(89)=-.27$, $p<.05$) and marginally significantly negatively correlated with this measure at the 5-year-old time point ($r(89)=-.20$, $p<.06$), demonstrating that parents who bestowed a greater frequency of math-specific corrective feedback tended to have children who exhibited lower scores on the math assessment concurrently and over time. Comparing general and math-specific parental feedback, the two forms of corrective feedback were strongly correlated ($r(89)=.90$, $p<.001$), while the correlations between the two forms of praise ($r(89)=.45$, $p<.001$) and two forms of affirmation ($r(89)=.60$, $p<.001$) were not as strong.

Parents' total utterances were significantly positively correlated with their general and math-specific praise (general: $r(89)=.57$, $p<.001$; math-specific: $r(89)=.43$, $p<.001$), affirmation in a non-praise context (general: $r(89)=.69$, $p<.001$; math-specific: $r(89)=.46$, $p<.001$), and corrective feedback (general: $r(89)=.54$, $p<.001$; math-specific: $r(89)=.54$, $p<.001$), indicating that parents who conversed more with their children tended to bestow greater amounts of general and math-specific parental feedback.

4.2.1 Parental Praise

As the distribution of parental person praise was strongly right-skewed, praise was combined across sub-types (person, process, and other) for the regression models. Regression statistics for general and math-specific parental praise are shown in Table 11 and Table 12. Model 1 was statistically significant and explained 13% of the variance in children's math outcomes, $F(3, 87)=5.45$, $p<.01$. A nonsignificant relation was found between general parental praise and children's math skills ($\beta=.20$, $p=.11$).

Model 2 showed that the frequency of general parental praise, child age, and total parental utterances explained 6% of the variance in children's expressive vocabulary, $F(3, 87)=2.99$, $p<.05$. The analysis revealed a significant relation between general parental praise and children's expressive vocabulary ($\beta=.29$, $p<.05$). In other words, one standard deviation increase in the frequency of general parental praise was associated with a .29 standard deviation increase in children's expressive vocabulary.

Model 3 was statistically significant and explained 12% of the variance in children's math outcomes, $F(3, 87)=5.11$, $p<.01$, while Model 4 was nonsignificant. Further, a nonsignificant relation was found between math-specific parental praise and children's math skills ($\beta=-.15$, $p=.18$). as well as children's expressive vocabulary ($\beta=.02$, $p=.85$).

4.2.2 Parental Affirmation

Regression statistics for general and math-specific parental affirmation are shown in Table 11 and Table 12. Model 5 explained 18% of the variance in children's math outcomes, $F(3, 87)=7.74$, $p<.001$. The analysis revealed a significant relation between general parental affirmation in a non-praise context and children's math skills ($\beta=.39$, $p<.01$). In other words, one standard deviation increase in the frequency of general parental affirmation was associated with a .39 standard deviation increase in children's math skills. In contrast, general parental affirmation in a non-praise context was not significantly related to children's expressive vocabulary ($\beta=.18$, $p=.21$) (Model 6).

Model 7 was statistically significant and explained 10% of the variance in children's math outcomes, $F(3, 87)=4.45$, $p<.01$, while Model 8 was nonsignificant. A nonsignificant relation was found between math-specific parental affirmation in a non-praise context and children's math skills ($\beta=.03$, $p=.81$), as well as children's expressive vocabulary ($\beta=-.03$, $p=.78$).

4.2.3 Parental Corrective Feedback

As the distribution of parental person corrective feedback was strongly right-skewed, corrective feedback was combined across sub-types (person, process, and other) for the regression models. Regression statistics for general and math-specific parental corrective feedback are shown in Table 11 and Table 12. Model 9 showed that the frequency of general parental corrective feedback, child age, and total parental utterances explained 21% of the variance in children's math skills, $F(3, 87)=9.04$, $p<.001$. The analysis revealed a significant relation between general parental corrective feedback and children's math skills ($\beta=-.39$, $p<.01$). In other words, one standard deviation increase in the frequency of general parental corrective feedback was associated with a .39 standard deviation decrease in children's math skills. In contrast, general parental corrective feedback was not significantly related to children's expressive vocabulary ($\beta=-.22$, $p=.07$) (Model 10).

Model 11 showed that the frequency of math-specific parental corrective feedback, child age, and total parental utterances explained 16% of the variance in children's math skills, $F(3, 87)=6.60$, $p<.001$. The analysis revealed a significant relation between math-specific parental corrective feedback and children's math skills ($\beta=-.27$, $p<.05$). In other words, one standard deviation increase in the frequency of math-specific parental corrective feedback was associated with a .27 standard deviation decrease in children's math skills. In contrast, parents' math-specific corrective feedback was not significantly related to children's expressive vocabulary ($\beta=-.15$, $p=.23$) (Model 12).

4.3 RQ2B: Relations Between Each Type of Parental Feedback and the Change in Children's Math Skills Between 4 and 5 Years of Age

4.3.1 Parental Praise

Regression statistics for general and math-specific parental praise are shown in Table 13. Although Model 13 did not explain significant variance in the change in children's math outcomes, $F(3, 87)=2.22$, $p=.09$, the frequency of general parental praise was significantly related to children's growth in math skills ($\beta=.28$, $p<.05$) after controlling for parents' total utterances and child age. In other words, one standard deviation increase in the frequency of general parental praise was associated with a .28 standard deviation increase in children's growth in math skills.

Model 14 did not explain significant variance in the change in children's math outcomes, $F(3, 87)=1.07$, $p=.37$, and the frequency of math-specific parental praise did not significantly relate to the change in children's math skills ($\beta=.14$, $p=.23$).

4.3.2 Parental Affirmation

Regression statistics for general and math-specific parental affirmation are shown in Table 13. Model 15 did not explain significant variance in the change in children's math outcomes, $F(3, 87)=0.81$, $p=.49$, and the frequency of general parental affirmation did not significantly relate to the change in children's math skills ($\beta=.12$; $p=.41$).

Model 16 did not explain significant variance in the change in children's math outcomes, $F(3, 87)=0.65$, $p=.58$, and the frequency of math-specific parental affirmation did not significantly relate to the change in children's math skills ($\beta=.06$, $p=.63$).

4.3.3 Parental Corrective Feedback

Regression statistics for general and math-specific parental corrective feedback are shown in Table 13. Model 17 did not explain significant variance in the change in children's math outcomes, $F(3, 87)=0.66$, $p=.58$, and the frequency of general parental corrective feedback did not significantly relate to the change in children's math skills ($\beta=-.06$, $p=.61$).

Model 18 did not explain significant variance in the change in children's math outcomes, $F(3, 87)=0.62$, $p=.61$, and the frequency of math-specific parental corrective feedback did not significantly relate to the change in children's math skills ($\beta=-.04$, $p=.73$).

4.4 RQ3A: Relations Between All Types of Parental Feedback and 4-Year-Old Children's Concurrent Math and Language Skills

Regression statistics for all types of general and math-specific parental feedback are shown in Table 11 and Table 12. Model 19 showed that all types of general parental feedback, child age, and total parental utterances explained 24% of the variance in children's math skills, $F(3, 87)=6.60$, $p<.001$. The analysis revealed a significant unique relation between general parental corrective feedback and children's math skills ($\beta=-.30$, $p<.05$). In other words, one standard deviation increase in the frequency of general parental corrective feedback was associated with a .30 standard deviation decrease in children's math skills, even when accounting for general parental praise ($\beta=.11$, $p=.32$) and general parental affirmation ($\beta=.26$, $p=.06$).

Model 20 was marginally significant and explained 7% of the variance in children's expressive vocabulary, $F(3, 87)=2.30$, $p<.06$. The frequency of general parental praise uniquely explained significant variance in children's expressive vocabulary (β=.25, p<.05). In other words, one standard deviation increase in the frequency of general parental praise was associated with a .25 standard deviation increase in children's expressive vocabulary, even when controlling for general parental affirmation (β=.08, p=.60) and general parental corrective feedback (β=-.16, p=.22).

Model 21 showed that all types of math-specific parental feedback, child age, and total parental utterances explained 16% of the variance in children's math skills at age four, F(3, 87)=4.31, p<.01. However, the analysis did not reveal a significant unique relation between math-specific parental praise (β=-.14, p=.37), affirmation (β=.19, p=.19), or corrective feedback (β=-.25, p=.06) and children's math skills. Similarly, Model 22 did not explain significant variance in children's expressive vocabulary at age four, F(3, 87)=1.21, p=.31. There were no significant unique relations between math-specific parental praise (β=.19, p=.27), affirmation (β=-.09, p=.55), or corrective feedback (β=-.22, p=.13) and children's expressive vocabulary.

4.5 RQ3B: Relation Between All Types of Parental Feedback and the Change in Children's Math Skills Between 4 and 5 Years of Age

Regression statistics for general and math-specific parental feedback are shown in Table 13. Model 23 did not explain significant variance in the change in children's math outcomes, F(3, 87)=1.36, p=.25. However, the frequency of general parental praise significantly uniquely related to children's growth in math skills (β=.27, p<.05). In other words, one standard deviation increase in the frequency of general parental praise was associated with a .27 standard deviation increase in children's growth in math skills between 4 and 5 years of age, even when controlling for general parental affirmation (β=.08, p=.62) and general parental corrective feedback (β=-.00, p=.99).

Model 24 did not explain significant variance in the change in children's math outcomes, $F(3, 87)=0.93$, p=.47. There were no significant unique relations between math-specific parental praise (β=.26, p=.13), affirmation (β=-.06, p=.69), or corrective feedback (β=-.17, p=.25) and the change in children's math skills.

5.0 Discussion

The present study explored the variability in parent feedback during three semi-structured dyadic interactions in the home environment and the relations between different types of parent feedback and children's math and language skills prior to entering formal schooling. Specifically, this study examined the valence of domain-general and domain-specific parental feedback, i.e., praise, affirmation, and corrective feedback, in relation to children's math and language abilities. Overall, there was considerable variability in the frequency and type of parents' feedback during the semi-structured interactions. General parental praise and affirmation in a non-praise context were positively correlated with child outcomes, while math-specific parental praise and affirmation in a non-praise context were negatively correlated with the math outcome at both time points and positively correlated with the language outcome. General and math-specific parental corrective feedback were negatively correlated with child outcomes. All types of parental feedback were positively correlated with total parental utterances.

Table 14 displays a summary of the regression statistics for all general and math-specific parental feedback models. When examining the relation between the total frequency of each type of general parent feedback and children's math and language abilities, general parental affirmation in a non-praise context and general parental corrective feedback were significantly related to children's concurrent math abilities and general parental praise was significantly related to children's concurrent language abilities as well as the difference in children's math abilities over a one-year period, while controlling for child age and total parental utterances. However, the only relation that remained significant for math-specific feedback was the relation between corrective feedback and children's concurrent math abilities. Potential explanations for these findings are discussed below. Overall, the findings highlight the importance of considering the valence of domain-general and domain-specific parental feedback as they related differentially to children's concurrent math and language abilities, as well as their growth in math abilities over a one-year span.

5.1 Variability in the Occurrence of Parental Feedback

Consistent with past findings (Gunderson et al., 2013; Swenson et al., 2016), the sample demonstrated considerable individual variability in the frequency of all types of parental feedback. Among the different categories of general and math-specific parental feedback, parents utilized affirmation in a non-praise context the most often. This is consistent with several studies showing that affirmation was the most common form of positive feedback given by teachers and classmates in a classroom environment, while praise was rarely used (Buriel, 1983; Reigel, 2008). Both criticism and praise are more detailed and stronger forms of feedback than affirmation in a non-praise context, which is a more simple and generalized form of feedback regarding the correctness or appropriateness of behavior (Brophy, 1981). In addition, corrective feedback is context-specific such that certain contexts prompt more parental corrective feedback than others. The book task and grocery task are not goal-directed activities, so there is not an objectively right or wrong way to complete the tasks and they allow the dyads to engage in "free play." So, two out of the three tasks lend themselves to affirmation more than praise and corrective feedback. Although their frequencies in the sample differed, parental praise and parental affirmation in a non-praise context were significantly positively correlated, suggesting that parents who frequently bestow praise, a more detailed form of positive feedback, also tend to frequently bestow affirmation in a non-praise context, a more generalized form of positive feedback.

Between the two other types of general and math-specific parental feedback, on average parents bestowed corrective feedback more often than praise, which is consistent with a study that found children in fifth through ninth grade received teacher criticism more than two times as often as praise (Parsons et al., 1982). Another study supports this idea by showing that parents seeking child mental health treatment bestowed criticism upon their 2- to 5-year-old children nearly three times as often as praise during a 15-minute free play session (Swenson et al., 2016). For parental praise in particular, other praise constituted the largest proportion of general and math-specific parental praise utterances. Gunderson and colleagues (2013) also observed this in their sample, noting that parents often give their children feedback with a general positive valence without specifying the target of their feedback. For general and math-specific corrective feedback, process corrective feedback was bestowed with the greatest frequency. Negative feedback that draws the learner's attention to errors in their performance can be used to prompt modifications of their previous utterances or behaviors, providing a learning opportunity and positively impacting their academic development (McDonough, 2005). The ability to utilize negative feedback in this manner has been observed in Genevan children between the ages of 4 and 9 years (Karmiloff-Smith & Inhelder, 1974), as well as in 3- and 4-year-old English-speaking Singaporean children (Nguyen & Lwin, 2014).

5.2 Zero-Order Correlations Between Parental Feedback and Child Outcomes

General parental praise and general parental affirmation in a non-praise context were positively correlated with the child outcome measures, while general parental corrective feedback was negatively correlated with the child outcome measures. Among this grouping, there were only three significant correlations. Parental praise was significantly positively correlated with children's expressive vocabulary, which suggests that children who received more parental praise were reported to have a larger expressive vocabulary. Parental corrective feedback was significantly negatively correlated with children's Woodcock-Johnson Applied Problems subtest scores at both time points, which suggests that children who received more parental corrective feedback demonstrated inferior math abilities.

Compared to the corresponding correlations for general parental feedback, the correlation between math-specific corrective feedback and children's math outcomes at the first time point was also significant, while the correlation at the second time point was marginally significant. The similar significance values for the general and math-specific correlations may stem from the strong correlation between general corrective feedback and math-specific corrective feedback. Potential explanations for these findings are discussed in the context of the corresponding regression models below. Also, the correlation between math-specific praise and children's expressive vocabulary was not significant, while the correlation between math-specific praise and children's math outcomes at the first time point was negative and marginally significant, both of which differed from the correlations for general praise. The latter correlation suggests that children with lower math skills tended to receive relatively more math-specific praise. This may be because children with lower math skills need more scaffolding to respond to parents' math-related prompts, so the dyads spend more time working toward the desired answer to the prompt and the parents have more opportunities to bestow math-specific praise to motivate their children.

Finally, all three types of general and math-specific parental feedback were significantly positively correlated with total parental utterances, which demonstrates that parents who had more verbal interactions with their children had more opportunities to bestow feedback. In addition, child age was not significantly correlated with any of the general or math-specific parental feedback types, which suggests that parents did not adjust their feedback based on child age, at least in this limited age range.

5.3 Relations Between Parental Praise and Child Outcomes

Although the different sub-groups of parent feedback (e.g., different sub-types of parent praise) were examined descriptively, due to the low frequency of certain sub-groups they were summed such that only the three main groups of parental feedback (i.e., praise, affirmation, and corrective feedback) were used in the regression analyses. General parental praise was positively related to children's expressive vocabulary and the change in children's math abilities after controlling for child age and total parental utterances, as well as uniquely related to these same measures after additionally controlling for the other two types of general parent feedback. This indicates that parents' positive feedback was not simply the opposite of corrective feedback such that children who provided more correct responses to parental prompts received more positive feedback and proportionally less negative feedback. Instead, parental praise was predictive of children's expressive vocabulary and change in math abilities above and beyond parental affirmation and parental corrective feedback. This suggests that there may be reasons why parents provide praise besides in response to their children's performance, such as using praise to motivate or engage their children during an activity or parents' inherent tendency to bestow praise on their children.

These findings are consistent with two studies that showed teacher praise was related to enhanced academic performance for upper elementary school children (Harris et al., 1986; Van Houten et al., 1975). However, this contrasts with the findings of Gunderson, Sorhagen, and colleagues (2018) showing that other praise, which made up the greatest proportion of total praise in their sample, was not significantly related to children's performance in math and reading comprehension measures years later.

A potential explanation for the results of the regression model for children's expressive vocabulary is that parents often bestowed praise after children provided verbal responses to their prompts such that children with superior expressive vocabulary may have been better equipped to answer parents' prompts and therefore may have received praise more often. Alternatively, the observed dyadic interactions may have been an accurate reflection of parents' inherent tendency to praise their children and the frequency of parental praise may have impacted children's mindsets, which may have influenced how they approached learning opportunities and challenges and responded to setbacks, which in turn may have impacted their math and language skill development. Gunderson, Sorhagen, and colleagues (2018) found support for this mechanism by showing that parental praise bestowed upon children between the ages of 1 and 3 years during naturalistic dyadic interactions indirectly predicted children's future academic achievement in math and reading comprehension measures 7 years later via their motivational frameworks.

However, it may take time for parental input to influence child outcomes, as children may not reflect on praise and their mindsets may not be fully developed at the young age of four, so praise may not yet shape child mindsets and therefore child outcomes (Brummelman & Thomaes, 2017). In support of this idea, Blackwell and colleagues (2007) found that the relation between adolescents' motivational frameworks and longitudinal academic measures grew stronger over time as adolescents encountered more learning opportunities and challenges. This supports the finding in this sample that general parental praise was significantly related to children's change in math abilities from age four to five but not their concurrent math abilities at age four.

Another possible explanation for the divergent relations between general parental praise and children's concurrent math abilities versus children's change in math abilities is that as children learn everyday mathematics prior to entering formal schooling at around age five (Ginsburg et al., 2008), they may need more encouragement to complete tasks involving math, so parents likely make a more concerted effort to praise younger children's responses in a way that overstates their actual performance with the aim of improving their math abilities (Reigel, 2008). Even though praise is a form of positive feedback, Lee and colleagues (2017) found that children were sensitive to the accuracy of parental praise: parental praise that was perceived by children as forced or not accurately reflecting their performance was predictive of decreased academic outcomes compared to parental praise accurately reflecting their performance. As a result of excessive praise, children may hold inflated views of their own abilities and set high expectations for future performance such that they experience increased pressure and concern about meeting those expectations, leading them to avoid future learning opportunities and execute self-handicapping strategies. This is characteristic of a fixed mindset (Mueller & Dweck, 1998), which has been shown to lead to decreased performance (Smiley & Dweck, 1994). This may explain why general parental praise was not positively related to 4-year-old children's concurrent math outcomes. However, a negative relation was not observed either, which gives more weight to the explanation that children may not reflect on praise at this young age.

A possible interpretation of the nonsignificant results of the regression model for children's concurrent math skills and the significant results of the regression model for children's expressive vocabulary is that prior research showed that many parents report spending less time teaching math at home compared to language, think of math as less of a personal strength compared to language, and view reading skills as more important than math skills (Cannon & Ginsburg, 2008). Parents may think it is not their responsibility to teach math and that children should learn math during formal schooling, so parents may not do many math activities with their children and may not adjust their verbal input to children's math skills to help them build those skills. In contrast, language is inherent in communication, so a lot of informal learning activities parents do with their children are reading activities. Parents may adjust their feedback based on how their children verbally respond to their general questions or prompts. Children who have better expressive vocabulary are likely better able to keep up with and respond to the parental language input, and thus could receive more parental feedback.

The nonsignificant results of the math-specific praise models suggest that the relation between general parental praise and children's change in math outcomes (as well as children's expressive vocabulary) is reflective of general academic abilities and is not driven by math-specific parental praise. This is in contrast with prior work showing that maternal support of 3-year-old children's math concepts learning had positive effects on their preschool and first-grade math outcomes, as well as their preschool reading achievement (Casey et al., 2018; Lombardi et al., 2017). One potential explanation is that children do not reflect on the domain-specific nature of praise at this young age such that praise in any domain improves children's academic outcomes generally. This demonstrates the importance of examining domain-specific forms of praise: some forms of praise may serve different functions such that they differentially relate to children's academic outcomes.

5.4 Relations Between Parental Corrective Feedback and Child Outcomes

General corrective feedback was negatively related to children's concurrent math abilities after controlling for child age and total parental utterances, as well as uniquely related to this same measure after additionally controlling for the other two types of general parent feedback. This indicates that parents' corrective feedback was not simply the opposite of positive feedback such that children who provided fewer correct responses to parental prompts received more corrective feedback and proportionally less positive feedback. Instead, parental corrective feedback was predictive of children's concurrent math abilities above and beyond parental praise and parental affirmation. This suggests that there may be reasons why parents provide corrective feedback besides in response to their children's performance, such as parents thinking it is particularly important to correct a certain type of behavior.

A potential explanation for the findings on the relation between general parental corrective feedback and children's concurrent math abilities is that 4-year-old children with lower math skills are less equipped to answer parents' math-related prompts such that they are more likely to answer them incorrectly or inappropriately and thus parents may provide more corrections. In addition, parents may use more math prompts with children who have lower math skills to help them build a stronger foundation of math concepts and they may often answer incorrectly due to their lower math skills, resulting in them receiving more of this type of feedback. Alternatively, parents in the sample may have tended to give similar amounts of corrective feedback to their children, but children with lower math skills may have spent more time on the same prompts and thus may have received more of the same repeated feedback.

Schachter (1991) noted that although children develop the ability to utilize negative feedback between the ages of 5 and 9 years, children between the ages of 4 and 9 years often do not respond to negative feedback and instead choose to hold onto their original incorrect hypotheses, which could prompt more negative feedback. Nguyen and Lwin (2014) found that 3- and 4-year-old English-speaking Singaporean children only adjusted their behavior 33% of the time following parental corrective feedback provided during dyadic interactions. This could explain the negative relations between general parental corrective feedback and children's academic outcomes if children with lower (versus greater) academic skills were also less responsive to parental corrections.

Another possibility is that the observed dyadic interactions may have been an accurate reflection of parents' inherent tendency to correct their children and the frequency of parental corrective feedback may have impacted children's mindsets, which may have influenced how they approached learning opportunities and challenges and responded to setbacks, which in turn may have impacted their math skill development. Cognitive evaluation theory supports this mechanism, as it suggests that negative feedback leads to lowered intrinsic motivation and self-evaluations of competence (Gunderson, Donnellan, et al., 2018). These attributes are characteristic of a fixed mindset, which could lead to decreased performance (Smiley & Dweck, 1994).

This suggests that for young children learning math skills over time, positive feedback may be more effective than negative feedback because it increases children's confidence in their abilities and outcome expectancy as opposed to negative feedback, which undermines children's confidence and outcome expectancy (Fishbach et al., 2010). The results from the general corrective feedback models elaborate upon prior work showing that teacher criticism of fourth- and fifth-grade students in a classroom of Anglo-American and minority students was negatively related to students' academic achievement (Buriel, 1983) by indicating that corrective feedback bestowed upon 4-year-old children in the home environment negatively impacts their math outcomes even before they enter formal schooling. This is in contrast with a study by McDonough (2005) that found college-aged students who received more negative teacher feedback and modified their output accordingly demonstrated greater academic development in an ESL classroom. The age of the participants in these studies suggests that the impact of corrective feedback on children's academic outcomes may vary based on child age. Older children with more experience in completing academic tasks may interpret negative feedback as signaling that more effort is needed for goal attainment, thereby prompting goal pursuit and resulting in improved academic achievement (Fishbach et al., 2010). Meanwhile, negative feedback may undermine the confidence and outcome expectancy of young children who are not as proficient in academic tasks, thereby hindering goal pursuit and resulting in reduced academic achievement. This could account for the observation that the young children in this sample who received more general corrective feedback demonstrated inferior concurrent performance on the math measure, while they did not demonstrate a significant difference in their performance on the math measure from age four to five.

In addition, although corrective feedback was significantly related to children's concurrent math skills, it was not significantly related to children's concurrent expressive vocabulary after controlling for child age and total parental utterances. A potential explanation for this finding is that parents may think it is more important to correct children's math responses than their language responses in the home environment prior to entering formal schooling. In addition, math responses have a greater degree of objective correctness than language responses such that children's responses to math-related prompts lend themselves to a greater amount of corrective feedback.

With regard to the math-specific corrective feedback models, math-specific corrective feedback was negatively related to children's math abilities after controlling for child age and total parental utterances. This suggests that the negative relation between general parental corrective feedback and children's concurrent math outcomes is at least partially driven by math-specific corrective feedback. A potential explanation for this finding is that children with lower math abilities may struggle with answering math-related prompts from parents and as a result parents may provide them with more math-specific corrective feedback.

Interestingly, general parental corrective feedback was uniquely related to children's concurrent math outcomes while general parental praise was uniquely related to the change in children's math outcomes. One potential explanation is that corrective feedback prompts children to immediately compare their current incorrect response with other alternatives to reach the correct response. Therefore, corrective feedback may be more reflective of children's concurrent skills and parents' perception of the need to improve those skills. Children learn everyday mathematics prior to entering formal schooling at around age five (Ginsburg et al., 2008), and once they enter formal schooling math concepts build upon each other such that children will continue to struggle with different math concepts as they age, prompting parents to bestow corrective feedback to ensure their children develop a strong foundation for mathematics. In contrast, praise prompts children to remember their current response so can repeat it at a temporally distant similar occasion. Thus, praise may be more necessary for long-term change and as such relates to the growth in children's math abilities from age four to five.

The positive direction of the general praise regression models and the negative direction of the general corrective feedback regression models may reflect the different functions of praise and corrective feedback in the home learning environment. Parents often bestow praise upon children to provide motivation while completing tasks. Henderlong and Lepper (2002) noted the utility of praise for boosting children's motivation and perceived competence, particularly when it is perceived as sincere, attributes their performance to causes within their control, provides attainable expectations, and promotes their autonomy. Following praise, the child is not required to make any adjustments to their response and instead knows to repeat the praised action or verbalization in future tasks, thereby strengthening their development of academic skills and allowing the dyad to move on to another aspect of the task.

In contrast, parents often provide their children with corrective feedback to scaffold their children's learning and acquisition of concepts. Scaffolding consists of parental elicitations that are contingent on the child's performance and facilitate the child answering the parent's questions and prompts, thereby fostering the development of problem-solving abilities and autonomy, particularly in goal-directed activities such as the magnet task (Mermelshtine, 2017). After children receive corrective feedback, they must realize that their original conception of the topic was incorrect and work to correct their actions or verbalizations, which means they must exert more effort in response to corrective feedback compared to praise. Otherwise, they will have an inaccurate academic foundation that will hinder them from advancing and learning progressively more difficult material. Also, children with inferior math skills may receive more corrective feedback regarding the same few concepts due to repeatedly struggling with responding to parental prompts as well as responding appropriately to parents' prior corrective feedback.

For the math-specific combined regression model, neither math-specific corrective feedback nor math-specific praise was uniquely related to any of the child outcomes after additionally controlling for the other two types of math-specific parent feedback. This could be due to the fact that all three math-specific feedback categories were highly positively correlated with each other ($r(89)=.70$, $r(89)=.62$, and $r(89)=.46$, all $p<.001$). This suggests that parents who provided one type of math-specific feedback also tended to provide the other types of math-specific feedback and that these variables represented similar or redundant information. However, the combined regression model was intended to estimate the relation for one feedback variable while holding the other feedback variables constant, which is difficult for strongly correlated variables. Therefore, multicollinearity may explain the lack of significant relations between any of the math-specific feedback variables and children's skills.

In addition, the strong correlations between math-specific feedback variables suggest that when the dyads discussed math concepts, parents may not have differentiated between the types of math-specific feedback such that they utilized the feedback types more consistently throughout the interaction compared to general feedback and the feedback types served similar functions. Also, children often needed more support or scaffolding to answer a math-related prompt compared to a prompt that did not involve math, which provided parents with more opportunities to bestow all three types of math-specific feedback during their scaffolding. For instance, parents often provided corrective feedback when their children initially struggled with the math-related prompt, followed by affirmation as children started to correctly respond to their scaffolding prompts, and lastly praise once children responded correctly to the initial prompt.

5.5 Relations Between Parental Affirmation and Child Outcomes

General affirmation in a non-praise context was positively related to children's concurrent math outcomes, but not expressive vocabulary, after only controlling for child age and total parental utterances. This finding is consistent with several studies that exhibited how teacher affirmation and positive feedback in general were significantly related to enhanced academic achievement of students (Buriel, 1983; Reigel, 2008). Buriel found that teachers provided certain groups of high achieving students with more affirmation, suggesting that teacher affirmation may be contingent upon student academic achievement. Similarly, children who had greater math abilities may have received more parental affirmation as a result.

However, once the other two types of general parental feedback were controlled for, this relation was no longer significant, suggesting that general affirmation in a non-praise context did not contribute unique variance to explaining children's math skills after accounting for the other general parental feedback types. This is in contrast with a study by Morris and Zentall (2014) showing that utterances labelled as verbal ambiguous praise, which were defined as affirmation in this study, bestowed upon kindergarteners were as motivating or more motivating than process praise. In addition, affirmation in a non-praise context was not significantly related to children's change in math outcomes after controlling for child age and total parental utterances in this sample. These two findings suggest that although the frequency of affirmation was greater than praise in these studies, children did not perceive all forms of positive feedback similarly such that any form of positive feedback resulted in improved academic outcomes, as suggested by Reigel (2008). Thus, affirmation may not be the most salient form of reinforcement for young children developing foundational math skills prior to formal schooling.

The nonsignificant results of the math-specific affirmation models suggest that the relation between general parental affirmation and children's concurrent math outcomes is reflective of general academic abilities and is not driven by math-specific parental affirmation. As with parental praise, this may be because children do not reflect on the domain-specific nature of affirmation at this young age such that affirmation in any domain improves children's academic outcomes generally. This demonstrates the importance of examining domain-specific forms of affirmation, which may serve different functions.

5.6 Strengths, Limitations, and Future Directions

One strength for the current study is that potentially confounding parent and child factors were controlled for in the regression models. Controlling for the total number of parental utterances during the semi-structured interactions allowed for the separation of the amount of parental talk, which is an established source of variation in children's math and language outcomes (Cristofaro & Tamis-LeMonda, 2011), from the frequency of parental feedback types in predicting children's math and language skills. In addition, controlling for child age isolated the effect of age on parental feedback and child outcomes, as older children may receive more parental feedback as a result of their higher level of expertise (Uscianowski et al., 2020) and they may have higher math and language abilities.

Although the inclusion of these covariates helped isolate the relations between the types of parental feedback and children's academic abilities, several potential causal variables were omitted from the regression models due to the small sample size or were not measured during data collection, such as the importance parents place on their children learning math skills and parents' math abilities. Prior research showed that the more parents valued math skills, the more they engaged in math-related activities with their young children to prepare them for formal schooling (Musun-Miller & Blevins-Knabe, 1998). Additionally, parents with a higher subjective math ability engaged in more number talk with their 5- and 6-year-old children (Elliott et al., 2017). Thus, future work should collect data on additional demographic characteristics to examine whether the relations between parental feedback types and child outcomes differ after accounting for other parent or dyad characteristics.

Future work should also examine other aspects of dyadic interactions that were not examined in this sample. For instance, child variables such as child temperament or responsiveness may impact how parents interact with their children during dyadic interactions and the frequency of feedback they provide. Regarding responsiveness, although parents in the sample may have provided similar frequencies of the different parental feedback types, children with inferior academic skills may have repeatedly struggled with responding to parental prompts or prior parental corrective feedback and received more corrective feedback regarding the same few concepts and thus received correspondingly less positive feedback. Also, Nguyen and Lwin (2014) noted that children's uptake of corrective feedback and thus the effectiveness of the feedback in influencing children's academic abilities may depend on the type of error in the child's response (e.g., quality and quantity) that prompted parental corrective feedback and the child's interest in the topic that the dyad is discussing.

In addition, parents' dynamic communicative input, which includes gestures, was not captured in the current coding scheme. Many parents in this sample utilized gestures to provide feedback to children and/or supplement their verbal feedback. In particular, the parents employed pointing and/or iconic gestures, which are hand and arm movements that draw the child's attention to and/or demonstrate the characteristics of certain objects, locations, or actions (Rohlfing, 2011). Prior research has found that gestures impact children's vocabulary development (Rohlfing et al., 2013) as well as children's development of spatial reasoning (Ehrlich et al., 2006). Also, the exact form of the parents' corrective feedback (e.g., clarification requests and confirmations) and the opportunities provided by the parent for the child's uptake of the feedback and adjustment of their response may impact children's uptake of corrective feedback and thus its effectiveness (Nguyen & Lwin, 2014). Therefore, future work should investigate parents' delivery of specific forms of corrective feedback and how parents complement their verbal feedback with gestures to contribute to their children's development of language and math skills.

Another strength of the current study is the use of semi-structured observations in the home environment, as these observations revealed how the parents and children in this sample play and interact with each other, as well as how often the parents provided feedback during tasks that resemble potential day-to-day activities the dyads could engage in outside of the data collection. Prior work examining the impact of parental feedback on child outcomes has tended to utilize self-report measures (Lee et al., 2017; Madjar et al., 2015; Pomerantz & Kempner, 2013) or experimental measures (Cimpian et al., 2007; Kamins & Dweck, 1999; Zentall & Morris, 2010). In contrast, in this sample parents were instructed to engage with their children as they normally would without informing them of what the researchers would be looking for during the interactions, as this likely would have impacted the amount and types of feedback they provided. This is a more reliable and valid measure than self-report data, which can easily be biased and thus can inaccurately represent parental feedback (Swenson et al., 2016).

Although the three semi-structured observational tasks were selected to provide parent-child dyads with opportunities to engage in math-talk and scaffolding, which lend themselves to parental feedback, and to represent tasks the dyads could engage in together outside of the data collection, the tasks all have some degree of structure and may not actually reflect the day-to-day interactions of the dyads. They may represent how parents and children interact under ideal situations (i.e., if they had access to the provided materials for a certain period of uninterrupted time with limited distractions) as opposed to how they naturally interact in their home environments. Future work should examine dyadic interactions in more naturalistic settings that are not as structured, such as measuring the feedback parents spontaneously bestow upon their children in the home environment (Gunderson et al., 2013), to increase the ecological validity of the results.

A notable limitation of this study is that certain categories of parental feedback occurred at a low frequency, particularly person praise and person corrective feedback, which required that the three sub-types of praise and corrective feedback be collapsed into single measures of total praise and total corrective feedback. This prevented the examination of the relation between different sub-types of praise and corrective feedback and child outcomes, which would have been a novel research aim for corrective feedback and would have allowed for comparisons with prior literature regarding the impact of the different sub-types of praise (Cimpian et al., 2007; Gunderson, Sorhagen, et al., 2018; Kamins & Dweck, 1999). Increasing the number of opportunities for parents to provide feedback in future work could allow for the observation of a greater frequency of these sub-types of parental feedback, which could reveal relations that were not observed in this sample. This could be achieved by diversifying the contexts in which parents and children are observed, increasing the amount of time that they spend on the provided activities, or observing their day-to-day interactions via a naturalistic approach.

In particular, it is possible that the relative frequencies of the different types of parental feedback may vary for different tasks such that certain activities stimulate the development of children's mindsets and thus cognitive skills more than others. Past research has used tasks that vary on this dimension: some studies utilized structured contexts including the classroom setting (Buriel, 1983; Reigel, 2008) while other studies used more natural contexts such as the everyday home environment (Gunderson, Sorhagen, et al., 2018). In this study, all tasks took place in the everyday home environment and were play-based, but the tasks varied based on the amount of structure. Parents bestowed the most praise and corrective feedback on their children in the magnet task. This may be due to the more straightforward and structured nature of the magnet task, as well as its potential unfamiliar nature for the dyads such that it may have been more difficult for the children to complete, which may have prompted parents to encourage their children by praising them more often. In contrast, the frequency of affirmation was closer across the three tasks, which may stem from the multiple uses of affirmation. Parents may naturally bestow affirmation in "free play" tasks like the book and grocery tasks to indicate comprehension, as well as in "guided play" tasks like the magnet task to indicate correctness, while praise and corrective feedback are solely used to provide valenced feedback. Therefore, future work should examine the possibility of the relations between parental feedback types and children's academic outcomes varying depending on the task by having dyads engage in a greater variety of tasks.

Additionally, the relations between parental feedback types and children's academic outcomes likely vary depending on the outcome utilized. Parents may provide a greater frequency of feedback that supports children's development of certain skills over others. For instance, the results from this sample may have differed if children had completed a spatial skills assessment, since the magnet task requires children to use spatial reasoning. The language assessment utilized in this study was a measure of expressive vocabulary, but this is just one aspect of language. There are other language skills that were not tested and could have resulted in different relations between parental feedback types and children's language outcomes. Thus, future work should utilize a greater range of child outcome measures that assess children's general and specific skills in different domains to determine whether parental feedback impacts children's skills in general or only specific skills. This work should also attempt to identify children's skills that are associated with parents' general feedback versus math-specific feedback.

Another limitation is that longitudinal regression models for children's change in expressive vocabulary could not be created due to the omission of the DVAP at the 5-year-old wave of data collection, which would have established temporal precedence and allowed for greater confidence in the direction of the relations, as well as well as the examination of how time impacts the strength of the relations. This also prevented the use of language skills as a comparison domain for the longitudinal regression models for children's change in math skills. Future work should examine the longitudinal relations between parental feedback types and children's change in expressive vocabulary as comparison models to determine whether any observed relations for children's change in math skills are domain-specific or reflective of general academic abilities.

Finally, as noted in the method section, the analytic sample for this study may not be generalizable to the broader population, as it was geographically restricted and included dyads who differed in children's expressive vocabulary and parents' household income from those who were excluded. Future work should include data from a larger and more diverse range of families and include protocols that are more effective at preventing corrupted data and participant dropout to increase the generalizability of the results.

5.7 Conclusion

Parental feedback has the potential to support children's math and language development in various ways. Parents' praise when their children were 4 years old was found to be individually and uniquely associated with children's concurrent expressive vocabulary and change in math skills from age four to five, parents' affirmation was found to be associated with children's concurrent math skills, and parents' corrective feedback was found to be individually and uniquely associated with children's concurrent math skills, above and beyond the total number of parental utterances and child age. However, out of all math-specific parental feedback models, only parents' math-specific corrective feedback and children's concurrent math skills were significantly associated, indicating that the relations between parental feedback and child outcomes are largely due to general feedback, not math-specific feedback. The results of this study provide insight into the contribution of parental feedback to children's academic outcomes in the home environment prior to formal schooling, expanding upon a body of prior work that primarily consists of research on the impact of parental and teacher feedback on school-aged children's academic success. This work has broader implications for the development and dissemination of interventions that can be implemented in preschool or community settings to aid parents in providing academically beneficial learning opportunities for their children. These interventions may contribute to the development of children's math and language skills before they enter formal schooling through fostering advantageous behaviors during learning opportunities, including a motivation to learn and a growth mindset.

6.0 Tables

Table 1 Positive Feedback Categories

Positive feedback category	Examples
Person praise	"Good girl"*
	"You're so smart"*
	"You're so nice"
	"You're so good at this"*
Process praise	"Good job / good idea"*
	"That's a great spot you picked"
	"Great placement"*
	"You tried really hard"*
	"I like how you put that shape there"*
Other praise	"Very good"*
	"Perfect"
	"Nice"
	"Wow / yay"*
	"It looks great"
	"That's a nice puzzle"*
Affirmation in a praise context (sub-category of other praise)	"That's right / you're right"*
	"Correct"*
	"That is it"*
	"You did it / you got it / you found it"*
	"There you go / there we go"*
	"You really did turn that thing on"*
	"I can't believe you made that"*
Affirmation in a non-praise context	"Yes / yeah"
	"Mmhm / uhhuh"
	"Okay / kay / alright"
	"Okay go ahead"
	"Thank you"

*Examples taken from Gunderson et al. (2013). All other examples are from semi-structured observations in the present study.

Table 2 Corrective Feedback Categories

Corrective feedback category	Examples
Person corrective feedback	"I'm very disappointed in you"*
	"You're not very good at this"
	"You need to be more careful"
Process corrective feedback	"Maybe you could think of another way to do it"*
	"That's not the right way to do it"
	"Keep trying / keep turning / keep going"
	"I think we need to turn it a different way"
	"I don't think you picked the right spot"
	"That shape doesn't go there"
	"Let's start over"
Other corrective feedback	"No"
	"Close / almost / not quite"
	"That doesn't look right"
	"That doesn't match the puzzle picture"
	"Well let's look at the picture"
	"That's not a table silly"

*Examples taken from Kamins & Dweck (1999). All other examples are from semi-structured observations in the present study.

Table 3 Math-Specific Talk Categories

Math-specific talk category	Definition	Example
Number talk	Praise, affirmation, or corrective feedback occurred after number talk	P: “How many foxes are there?” C: “Eight” P: “That’s right” [affirmation after number talk]
Spatial talk	Praise, affirmation, or corrective feedback occurred after spatial talk	P: “Where does that piece go?” C: “I don’t know” P: “Okay let’s look at the picture and try to break it down” C: “Here?” P: “You got it” [other praise after spatial talk]
Both number and spatial talk	Praise, affirmation, or corrective feedback occurred after number AND spatial talk	P: “Can you put both circles on top of the square?” C: “Okay one two” P: “Good job” [praise after both number and spatial talk]

Table 4 Descriptive Statistics of General Parental Feedback Types Across Tasks

Feedback type (*n=91*)	Book		Grocery		Magnet		Total	
	M (SD)	Range	*M* (SD)	Range	*M* (SD)	Range	*M* (SD)	Range
Praise	3.45 (3.84)	0-20	4.59 (4.43)	0-26	16.41 (9.17)	1-36	24.45 (13.41)	3-58
Person praise	.12 (.51)	0-4	.26 (.74)	0-4	.31 (.59)	0-3	.69 (1.28)	0-7
Process praise	.65 (1.16)	0-6	.87 (1.22)	0-6	3.64 (2.98)	0-11	5.15 (4.00)	0-15
Other praise	2.68 (3.20)	0-18	3.46 (3.47)	0-19	12.46 (7.97)	1-35	18.60 (11.17)	2-51
Affirmation in a non-praise context	20.40 (10.65)	2-53	32.82 (15.07)	7-78	28.19 (15.55)	2-79	81.41 (32.44)	20-195
Corrective feedback	4.54 (4.68)	0-23	7.16 (5.73)	0-29	23.41 (13.89)	1-82	35.11 (19.42)	2-102
Person corrective feedback	0 (0)	0-0	.05 (.27)	0-2	0 (0)	0-0	.05 (.27)	0-2
Process corrective feedback	1.20 (2.18)	0-11	4.52 (4.23)	0-24	16.51 (10.33)	0-57	22.22 (13.31)	2-67
Other corrective feedback	3.34 (3.24)	0-12	2.59 (2.57)	0-14	6.90 (5.75)	0-25	12.84 (8.33)	0-37
Total feedback	28.38 (14.83)	3-64	44.58 (18.25)	15-114	64.81 (26.94)	14-142	140.97 (48.48)	45-256

Table 5 Skew and Kurtosis for General Parental Feedback Types Across Tasks

Feedback type (*n=91*)	Book		Grocery		Magnet		Total	
	Skew	Kurtosis	Skew	Kurtosis	Skew	Kurtosis	Skew	Kurtosis
Praise	1.87	7.37	2.05	8.94	.36	2.21	.42	2.49
Person praise	5.65	39.29	3.13	12.74	2.08	7.59	3.05	14.26
Process praise	2.61	11.24	1.94	7.26	.62	2.46	.52	2.22
Other praise	2.16	9.36	2.21	9.91	.62	2.71	.57	2.80
Affirmation in a non-praise context	.60	3.43	.89	3.71	.91	3.63	.87	4.29
Corrective feedback	1.35	4.94	1.18	4.81	1.27	5.79	1.06	4.24
Person corrective feedback	--	--	5.40	33.61	--	--	5.40	33.61
Process corrective feedback	2.42	9.10	1.61	6.95	1.16	5.02	1.23	4.62
Other corrective feedback	.97	2.99	1.47	6.23	1.31	4.46	.63	2.80
Total feedback	.22	2.11	.95	4.36	.35	2.77	.24	2.66

Table 6 Descriptive Statistics of Math-Specific Parental Feedback Types Across Tasks

Feedback type (*n=91*)	Book		Grocery		Magnet		Total	
	M (SD)	Range	*M* (SD)	Range	*M* (SD)	Range	*M* (SD)	Range
Math-specific praise	.81 (1.44)	0-7	1.15 (2.01)	0-12	6.29 (7.17)	0-30	8.25 (9.10)	0-37
Person praise	.05 (.35)	0-3	.04 (.21)	0-1	.09 (.32)	0-2	.19 (.67)	0-4
Process praise	.13 (.43)	0-3	.27 (.76)	0-5	1.33 (2.21)	0-10	1.74 (2.75)	0-12
Other praise	.63 (1.14)	0-5	.84 (1.34)	0-7	4.87 (5.60)	0-25	6.33 (6.96)	0-32
Math-specific affirmation in a non-praise context	6.37 (6.09)	0-33	8.11 (7.33)	0-37	10.55 (10.97)	0-50	25.03 (19.39)	2-77
Math-specific corrective feedback	1.73 (3.08)	0-18	3.32 (3.39)	0-17	15.59 (11.51)	0-65	20.64 (14.91)	1-76
Person corrective feedback	0 (0)	0-0	0 (0)	0-0	0 (0)	0-0	0 (0)	0-0
Process corrective feedback	.92 (1.90)	0-11	2.53 (2.99)	0-15	12.43 (9.07)	0-48	15.88 (11.37)	1-53
Other corrective feedback	.80 (1.63)	0-8	.79 (1.01)	0-4	3.16 (4.05)	0-17	4.76 (5.14)	0-24
Total math-specific feedback	8.93 (8.85)	0-42	12.62 (10.01)	1-42	32.44 (25.15)	2-127	53.92 (36.91)	5-161

Table 7 Skew and Kurtosis for Math-Specific Parental Feedback Types Across Tasks

Feedback type (*n=91*)	Book		Grocery		Magnet		Total	
	Skew	Kurtosis	Skew	Kurtosis	Skew	Kurtosis	Skew	Kurtosis
Math-specific praise	2.30	8.27	2.68	12.12	1.35	4.18	1.25	3.77
Person praise	7.39	60.77	4.45	20.80	3.87	18.45	4.56	25.06
Process praise	4.20	24.58	3.75	19.82	1.95	6.33	1.77	5.36
Other praise	2.07	6.66	2.10	8.00	1.46	4.69	1.44	4.66
Math-specific affirmation in a non-praise context	1.82	7.00	1.56	5.55	1.35	4.34	.97	2.91
Math-specific corrective feedback	3.19	14.97	1.41	5.15	1.50	6.15	1.47	5.69
Person corrective feedback	--	--	--	--	--	--	--	--
Process corrective feedback	2.93	12.91	1.74	6.45	1.50	5.94	1.45	5.38
Other corrective feedback	3.06	12.55	1.28	4.09	1.62	5.03	1.54	5.16
Total math-specific feedback	1.55	5.24	1.12	3.53	1.20	4.29	.91	3.03

Table 8 Descriptive Statistics of Child Outcomes and Covariates

Variable (*n=91*)	Dependent measure	*M* (SD)	Range
Woodcock-Johnson			
Applied Problems subtest	Total number of correct trials	15.30 (3.98)	1-26
Time 1	Standardized score	116.32 (11.32)	71-147
Time 2	Total number of correct trials	17.30 (5.96)	5-49
	Standardized score	104.87 (17.43)	55-151
Developmental Vocabulary			
Assessment for Parents	Number of words indicated	108.54 (26.75)	29-173
Time 1	out of 212		
Child age	Years	4.41 (.30)	4.00-4.96
Total parent utterances in all tasks	Number of utterances	400.70 (108.34)	141.00-664.00

Table 9 Correlations Between General Parental Feedback Types, Child Outcomes, and Covariates

Measure	1	2	3	4	5	6	7
1. Praise							
2. Affirmation in a non-praise context	.48***						
3. Corrective feedback	.20	.17					
4. WJ Applied Problems subtest score at time 1	.06	.10	-.35***				
5. DVAP score at time 1	.26*	.17	-.10	.47***			
6. WJ Applied Problems subtest score at time 2	.17	.10	-.26*	.74***	.47***		
7. Total parental utterances	.57***	.69***	.54***	-.13	.12	-.09	
8. Child age	.02	-.02	.01	.33**	.16	.32**	.05

^*p*<.06, **p*<.05, ***p*<.01, ****p*<.001

Table 10 Correlations Between Math-Specific Parental Feedback Types, Child Outcomes, Covariates, and General Parental Feedback Types

Measure	1	2	3	4	5	6	7
1. Math-specific praise							
2. Math-specific affirmation in a non-praise context	.70***						
3. Math-specific corrective feedback	.62***	.46***					
4. WJ Applied Problems subtest score at time 1	-.21^	-.05	-.27*				
5. DVAP score at time 1	.05	.02	-.04	.47***			
6. WJ Applied Problems subtest score at time 2	-.07	-.00	-.20^	.74***	.47***		
7. Total parental utterances	.43***	.46***	.54***	-.13	.12	-.09	
8. Child age	-.07	-.01	.02	.33**	.16	.32**	.05
9. Praise	.45***						
10. Affirmation in a non-praise context	.31**	.60***					
11. Corrective feedback	.40***	.26*	.90***				

^*p*<.06, **p*<.05, ***p*<.01, ****p*<.001

Table 11 Regression Analyses Predicting 4-Year-Old Children's Woodcock-Johnson Applied Problems Subtest Scores From General and Math-Specific Parental Praise, Affirmation in a Non-Praise Context, and Corrective Feedback

Variable (*n=91*)	Model 1	Model 3	Model 5	Model 7	Model 9	Model 11	Model 19	Model 21
	B (*SE*)							
General parental feedback								
Praise	.06						.03	
	(.04)						(.03)	
Affirmation in a non-praise context			.05**				.03	
			(.02)				(.02)	
Corrective feedback					-.08**		-.06*	
					(.02)		(.02)	
Math-specific parental feedback								
Math-specific praise		-.06						-.06
		(.05)						(.07)
Math-specific affirmation in a non-praise context				.01				.04
				(.02)				(.03)
Math-specific corrective feedback						-.07*		-.07
						(.03)		(.04)
Child age	4.57**	4.38**	4.82***	4.57**	4.50**	4.53**	4.69***	4.44**
	(1.32)	(1.33)	(1.28)	(1.34)	(1.25)	(1.30)	(1.24)	(1.31)
Total parental utterances	-.01*	-.00	-.02**	-.01	.00	.00	-.01	-.00
	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.01)	(.00)
R^2/adjusted R^2	.16/.13	.15/.12	.21/.18	.13/.10	.24/.21	.19/.16	.28/.24	.20/.16
F for R^2	5.45**	5.11**	7.74***	4.45**	9.04***	6.60***	6.60***	4.31**

^*p*<.06, **p*<.05, ***p*<.01, ****p*<.001

Table 12 Regression Analyses Predicting 4-Year-Old Children's Developmental Vocabulary Assessment for Parents Scores From General and Math-Specific Parental Praise, Affirmation in a Non-Praise Context, and Corrective Feedback

Variable (*n=91*)	Model 2	Model 4	Model 6	Model 8	Model 10	Model 12	Model 20	Model 22
	B (*SE*)							
General parental feedback								
Praise	.58*						.50*	
	(.25)						(.25)	
Affirmation in a non-praise context			.15				.06	
			(.12)				(.12)	
Corrective feedback					-.31		-.22	
					(.17)		(.18)	
Math-specific parental feedback								
Math-specific praise		.07						.55
		(.34)						(.49)
Math-specific affirmation in a non-praise context				-.05				-.12
				(.16)				(.21)
Math-specific corrective feedback						-.27		-.40
						(.22)		(.26)
Child age	14.00	14.05	14.68	13.77	13.63	13.75	14.14	15.01
	(9.19)	(9.52)	(9.40)	(9.47)	(9.29)	(9.39)	(9.19)	(9.50)
Total parental utterances	-.01	.02	-.00	.03	.06	.05	-.00	.05
	(.03)	(.03)	(.04)	(.03)	(.03)	(.03)	(.05)	(.03)
R^2/adjusted R^2	.09/.06	.04/.00	.05/.02	.04/.00	.07/.04	.05/.02	.12/.07	.07/.01
F for R^2	2.99*	1.13	1.66	1.14	2.25	1.62	2.30^	1.21

^*p*<.06, **p*<.05, ***p*<.01, ****p*<.001

Table 13 Regression Analyses Predicting the Change in Children's Woodcock-Johnson Applied Problems Subtest Scores Between 4 and 5 Years of Age From General and Math-Specific Parental Praise, Affirmation in a Non-Praise Context, and Corrective Feedback

Variable (*n=91*)	Model 13	Model 14	Model 15	Model 16	Model 17	Model 18	Model 23	Model 24
	B (*SE*)							
General parental feedback								
Praise	.08*						.08*	
	(.04)						(.04)	
Affirmation in a non-praise context			.02				.01	
			(.02)				(.02)	
Corrective feedback					-.01		-.00	
					(.03)		(.03)	
Math-specific parental feedback								
Math-specific praise		.06						.12
		(.05)						(.08)
Math-specific affirmation in a non-praise context				.01				-.01
				(.02)				(.03)
Math-specific corrective feedback						-.01		-.05
						(.03)		(.04)
Child age	1.92	2.08	1.98	1.93	1.89	1.90	1.97	2.19
	(1.41)	(1.44)	(1.45)	(1.45)	(1.45)	(1.45)	(1.43)	(1.45)
Total parental utterances	-.01	-.00	-.00	-.00	.00	.00	-.01	-.00
	(.00)	(.00)	(.01)	(.00)	(.00)	(.00)	(.01)	(.00)
R^2/adjusted R^2	.07/.04	.04/.00	.03/-.01	.02/-.01	.02/-.01	.02/-.01	.07/.02	.05/-.00
F for R^2	2.22	1.07	.81	.65	.66	.62	1.36	.93

^*p*<.06, **p*<.05, ***p*<.01, ****p*<.001

Table 14 Summary of Regression Statistics for General and Math-Specific Parental Feedback Models

Feedback type (*n=91*)	Woodcock-Johnson Applied Problems subtest score	Developmental Vocabulary Assessment for Parents score	Difference in Woodcock-Johnson Applied Problems subtest scores between time 2 and time 1
General praise	(+)	*(+)	*(+)
Math-specific praise	(–)	(+)	(+)
General affirmation in a non-praise context	**(+)	(+)	(+)
Math-specific affirmation in a non-praise context	(+)	(–)	(+)
General corrective feedback	**(–)	(–)	(–)
Math-specific corrective feedback	*(–)	(–)	(–)
General praise, affirmation, and corrective feedback	Praise (+) Affirmation (+) Corrective feedback *(–)	Praise *(+) Affirmation (+) Corrective feedback (–)	Praise *(+) Affirmation (+) Corrective feedback (–)
Math-specific praise, affirmation, and corrective feedback	Praise (–) Affirmation (+) Corrective feedback (–)	Praise (+) Affirmation (–) Corrective feedback (–)	Praise (+) Affirmation (–) Corrective feedback (–)

^$p<.06$, *$p<.05$, **$p<.01$, ***$p<.001$
(+)Positive association
(–)Negative association

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