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Examining a Factor Structure of Home Math Activities by Math Subdomain With Associations to Children's Math Skills

Rebecca McGregor Reiner [1], Diana Leyva [1], Andrew Ribner [1,2], Melissa E. Libertus [1]

[1] *Department of Psychology, Learning Research and Development Center, University of Pittsburgh, Pittsburgh, PA, USA.* **[2]** *Department of Psychology, Chatham University, Pittsburgh, PA, USA.*

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Corresponding Author: Rebecca McGregor Reiner, Learning Research and Development Center, University of Pittsburgh, 3420 Forbes Avenue, Sixth Floor, Pittsburgh, PA 15260, USA. Phone number: +1 412-624-7068. E-mail: rem166@pitt.edu

Supplementary Materials: Materials [see Index of Supplementary Materials]

Abstract

Evidence of positive associations between the frequency of home math activities and preschool children's math skills is mixed, and the operationalization of home math activities varies across studies. We test whether home math activities can be grouped by activity factors based on the math subdomain they target (i.e., counting and cardinality, comparison, number identification, addition and subtraction, and patterning) and examine associations between these activity factors and child math skills. Data were collected from 78 parents and their four-year-old children in the United States. Parents completed a home math activities survey, and children completed math assessments. Confirmatory Factor Analyses (CFA) indicated a well-fitting model with the five activity factors (one factor per subdomain) and a sixth factor for activities that could incorporate multiple subdomains. Structural Equation Modeling (SEM) analyses indicated positive associations between activity factors and child math skills for counting and cardinality, comparison, addition and subtraction, and patterning, but not for number identification. Results reveal that this model is appropriate for older four-year-old children closer to the beginning of kindergarten but is not appropriate for younger four-year-old children. This study suggests the possibility of operationalizing home math activities by activity factors based on math subdomains.

Keywords

parent, home, preschool, math, framework, factor analysis

Highlights

- Home math activity factors by math subdomain were examined and associations to preschool children's math skills were explored.
- Parent-report home math activities were related to child math skills in some math subdomains, but not others.
- The home math activity factors by math subdomain were more appropriate for older four-year-old children compared to younger.
- Specific math subdomain is a valuable way to operationalize home math activities.

Parents support their children's math development before the start of school through a variety of activities, such as playing games, reading books, and cooking together (Elliott et al., 2023). Researchers have extensively examined individual differences in engagement with home math activities to understand how they relate to children's early math development (Eason et al., 2022; Hornburg et al., 2021). However, research on the associations between the frequency of home math activities and preschool children's math skills is mixed, with some finding positive associations (LeFevre et al., 2009; Skwarchuk et al., 2014), some finding negative associations (Silinskas et al., 2010), and some finding null associations (De Keyser et al., 2020; Trickett et al., 2022). One possible explanation for these mixed results is the use of diverse operationalizations of home math activities. Below we define the early math skills that parents are supporting during these home math activities, discuss each of the main ways to operationalize home math activities and their relations to child math skills, and then offer an additional way to operationalize home math activities and examine relations to child math skills.

Children's Math Skills

While there are many ways to characterize components of mathematics, five broad subdomains have emerged from educational and cognitive perspectives for preschool children's math development: a) counting and cardinality (i.e., understanding one-to-one correspondence, the stable and ordinal sequence of numbers, and the value of a set is the final number in a counting sequence), b) comparison (i.e., comparing using terms like "more", "less", "most", and "least"), c) number identification (i.e., connecting a verbal word to a written number symbol), d) addition and subtraction (i.e., learning the rules that govern arithmetic and understand the relations between parts and a whole), and e) patterning (i.e., recognizing, replicating, and completing patterns; National Research Council, 2009; Purpura & Lonigan, 2015).

Each subdomain represents a differentiable set of skills that contributes to success in later mathematics, though there are correlations between the separate skills. Counting and cardinality skills in preschool are positively associated with addition and subtraction skills (Dowker, 2008), and comparison skills in preschool are positively associated with counting and cardinality and addition and subtraction skills (Purpura & Lonigan, 2013). Number identification skills in preschool are positively related to skills in counting and cardinality and addition and subtraction (Litkowski et al., 2020), as well overall math achievement (Chu et al., 2016). Addition and subtraction skills in kindergarten positively predict children's math performance in third grade and gains in math achievement from first to third grade (Jordan et al., 2009). Patterning skills in preschool are positively associated with concurrent general math knowledge in preschool (Rittle-Johnson et al., 2019; Zippert et al., 2019). Many of these math subdomains in preschool are also predictive of fifth grade math achievement (Nguyen et al., 2016; Rittle-Johnson et al., 2017). Researchers have called for a greater focus on the measurement and assessment of individual math subdomains to determine the factors that influence children's development of these specific math skills (Dearing et al., 2012; Rittle-Johnson et al., 2019).

We acknowledge that there are other important subdomains of math development in preschool which also predict later mathematics, such as spatial skills (i.e., the ability to visualize and mentally manipulate spatial information, copy and distinguish between shapes, and hold the location of objects in working memory; Rittle-Johnson et al., 2019). However, despite the importance of spatial skills in early childhood, parents report very low frequencies of engaging with spatial activities with their four-year-olds, leading some researchers to suggest that these activities may not be appropriate for this age (Zippert & Rittle-Johnson, 2020). In fact, most studies of early spatial activities use an older sample than the four-year-olds in the current study (first graders in Dearing et al., 2012; 3-8-year-olds in Hart et al., 2016; 4-7-year-olds in Jirout & Newcombe, 2015). Therefore, we focused exclusively on the five math subdomains reviewed above.

Home Math Activities Frameworks

Home math activities have been operationalized in a variety of ways across the literature. Below, we discuss the primary approaches, with an emphasis on the number and type of constructs, as well as the methods used to identify these constructs (for a more extensive review, see Daucourt et al., 2021).

Average Frequency of Home Math Activities With One Construct

Many studies operationalize home math activities as a single construct and calculate an average frequency of engagement across all activities (Anders et al., 2012; Blevins-Knabe & Musun-Miller, 1996; Cheung et al., 2020; De Keyser et al., 2020; Napoli & Purpura, 2018; Silinskas et al., 2010; Trickett et al., 2022). Some of these studies find positive associations between this single construct and children's math skills (Anders et al., 2012; Cheung et al., 2020; Napoli & Purpura, 2018; Trickett et al., 2022) while others report null (Blevins-Knabe & Musun-Miller, 1996; De Keyser et al., 2020) or negative (Silinskas et al., 2010) associations. While using one single construct is simpler, it obscures the nuance and complexity that exists within the frequencies with which parents and children engage in different math activities at home and, simplicity aside, may have limited psychometric support (e.g., Dierendonck et al., 2021; Elliott et al., 2023; Susperreguy et al., 2020). This approach also fails to consider how certain activities may facilitate the development of some skills but not others.

Average Frequency of Home Math Activities With Multiple Constructs

Other studies have also used an average frequency of math activities but have identified more than one construct. One approach has been to compare constrained math activities, or teachable activities that children can master, and unconstrained math activities, or activities that develop gradually through experience rather than direct teaching (McCormick et al., 2020). Frequency of unconstrained math activities, but not constrained math activities, was related to children's math skills. Another study that used an average frequency of math activities categorized activities into five constructs: direct teaching of number skills, applications of numbers, games, creating and constructing, and play and using tools (Ramani et al., 2015). There were positive associations between the frequency of direct teaching of math activities and children's foundational (e.g., counting, number identification) and advanced (e.g., cardinality, magnitude comparison) number skills and positive associations between the frequency of games and children's foundational number skills. Compared with using one construct, using multiple allows researchers to identify associations between certain categories of home math activities and children's math skills. However, the use of mean scores to assess a construct imposes certain assumptions that fail to accurately reflect the math activities as manifested in children's home environments and thus limit their methodological rigor. As a result, some researchers have examined constructs of home math activities through identifying multiple latent variables.

Latent Variable Approaches With Home Math Activities and Parental Expectations Constructs

A few studies have used latent variable approaches to operationalize home math activities as a component of the home math environment that includes other influences such as parental expectations (i.e., the extent to which parents expect children to have mastered certain domain-relevant skills in the future, such as having a mastery of addition up to 10 by the end of kindergarten; Kleemans et al., 2012; Segers et al., 2015). Principal axis factoring with a set of nine items suggested a two-factor model with one factor representing parent-child numeracy activities and one factor representing parents' numeracy expectations (Kleemans et al., 2012). Results showed that both factors were positively associated with children's numeracy skills. Another study found the same two-factor model using Principal Component Analysis (PCA) with 11 items measuring parent-child numeracy activities and parents' numeracy expectations and found positive associations to children's numeracy skills (Segers et al., 2015). Because these studies separated numeracy activities from parental numeracy expectations, they did not further disentangle the types of activities.

Latent Variable Approaches With Formal and Informal Home Math Activity Constructs

Another operationalization of home math activities is the distinction between formal or direct math activities (i.e., activities that involve explicit teaching of math concepts) and informal or indirect math activities (i.e., everyday activities that implicitly teach math concepts; Manolitsis et al., 2013; Skwarchuk et al., 2014). One study used PCA with five items, identified one formal numeracy factor, and found a positive relation between this factor and children's counting skills at the beginning of kindergarten (Manolitsis et al., 2013). Another study also used PCA to identify a two-factor model from 12 items (plus one that did not load onto either factor), with one factor for advanced formal numeracy (e.g., learning simple sums) and one factor for basic formal numeracy (e.g., reciting numbers in order; Skwarchuk et al., 2014). Results showed a positive relation between the advanced formal numeracy factor and children's symbolic number knowledge. This approach strengthens previous operationalizations of home math activities by using more psychometrically sound methodology, but individual activities are at times inconsistently defined as formal/direct versus informal/indirect and there is mixed evidence about which factors are associated with children's math skills (Elliott et al., 2023).

Latent Variable Approaches With Activity Features Constructs

Another way to operationalize home math activities is by the features of the activities being used (LeFevre et al., 2009; Mutaf Yıldız et al., 2018). Two studies used the same 20 items relevant to home math activities, conducted PCA, and identified similar four-factor models, with factors for number practices/skills, games, applications, and number books. While one found a positive relation between games and children's math knowledge (LeFevre et al., 2009), the other found positive associations between games and children's pictorial calculations skills, between applications and children's symbolic number line estimation skills, and between number practices and children's enumeration skills (Mutaf Yıldız et al., 2018). These studies suggest that features of the activity, such as a game board or book, may be a key component to our understanding of home math activities.

Math Subdomain Constructs

Across this literature, most studies structure their framework around the activity itself. However, an additional framework is to operationalize home math activities based on the math subdomain that a particular activity is targeting. Some studies have used average frequency of math activities to identify constructs in this way, while others have used latent variable modeling approaches to combine math subdomain constructs with other frameworks.

Average Frequency of Home Math Activities — Two studies to date have operationalized home math activities exclusively as the type of math skill being targeted (Leyva et al., 2021; Missall et al., 2017). One study identified five constructs targeting numbers and operations, geometry, measurement, data analysis, and algebra (Missall et al., 2017) while the other identified five constructs targeting counting and cardinality, set comparison, number identification, addition and subtraction, and patterning (Leyva et al., 2021). The constructs identified by Missall and colleagues (2017) reflect the primary categories of math standards in educational settings, while those identified by Leyva and colleagues (2021) reflect a subset of the skills involved in math learning in early childhood. While Missall and colleagues (2017) did not examine associations to child math skills, Leyva and colleagues (2021) found some positive associations between home math activities and math skills. Specifically, frequency of home math activities in set comparison, addition and subtraction, and patterning were positively associated with children's math skills in those same subdomains, while frequency of home math activities and math skills in counting and cardinality and number identification were not associated.

Latent Variable Approaches — Three studies have used latent variable approaches to identify constructs, some of which are centered around direct/indirect activities and features of activities, while others are centered around the math subdomain being targeted. Hart and colleagues (2016) used Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM) to identify a bifactor model of 23 items (from a total of 48) with a general home math activities factor and three specific factors for direct numeracy, indirect numeracy, and spatial activities. The general home math activities factor was positively associated with parents' report of their child's math skills and the specific spatial factor was negatively associated with parents' report of their child's math skills. A later study attempting to replicate and extend the work of Hart and colleagues (2016) used CFA and SEM to identify a bifactor model with a general home math activities factor and two specific factors: one of direct and indirect numeracy activities and one of spatial activities (Purpura et al., 2020). Subsequent analyses also revealed that the direct and indirect numeracy activities factor was positively associated with children's numeracy skills. Another study used Exploratory Factor Analysis (EFA) and CFA from 28 items (excluding 10 that did not load onto a factor) to identify a five-factor model of home math activities, with factors for counting, parent-child interaction, TV programs, shape, and computer math games (Cahoon et al., 2021). This study did not examine associations with children's math skills.

The operationalization of home math activities by targeted math subdomain is valuable for several reasons, including for the development of effective interventions and for communication to parents of young children, particularly because parents may engage in activities focused on specific math subdomains at different frequencies. Recent research found large variability in parents' report of the appropriateness of certain math skills for young children, rating some items (e.g., count a row of 15 objects) as very appropriate and other items (e.g., answer questions by adding and subtracting small numbers) as much less appropriate (Douglas et al., 2023; Ehrman et al., 2023). In addition, while many studies measuring home math activities focus on components of numeracy development (Blevins-Knabe & Musun-Miller, 1996; LeFevre et al., 2009; Skwarchuk et al., 2014), others have called for the inclusion of subdomains such as patterning (Zippert & Rittle-Johnson, 2020) and spatial skills (Dearing et al., 2012; Purpura et al., 2020) in the measure of home math activities. Previous studies have identified a construct of home math activities specific to spatial activities (Hart et al., 2016), but no studies to date have explored whether patterning activities might reflect their own construct as well.

Targeting a particular subdomain rather than a type of activity also helps to capture the nuance of what parents and children are actually doing in these activities, which is unclear when identifying constructs based on the type of activity. For example, one classic survey item of an informal/indirect activity asks parents about the frequency with which they "play board games with a die or spinner" with their child (LeFevre et al., 2009; Purpura et al., 2020; Skwarchuk et al., 2014; Thompson et al., 2017). However, it is unclear what math activities parents are doing during these games. They could be "counting objects" by counting spaces as they move a piece, "identifying names of written numbers" by discussing numbers on the spinner, or "using the terms 'more' or 'less'" by comparing which roll of the die has a higher number, all of which are other home math activity survey items used in these same studies. By examining a factor structure based on specific math subdomains, we aim to deepen our understanding of ways to operationalize home math activities and explore how factors of home math activities focused on specific math subdomains are promoting children's math development. This is an important precursor to the development of effective targeted intervention.

Current Study

The current study combined the latent variable modeling employed by previous research (Hart et al., 2016; LeFevre et al., 2009; Manolitsis et al., 2013; Mutaf Yıldız et al., 2018; Purpura et al., 2020; Skwarchuk et al., 2014) with the emphasis on math subdomain constructs made by others (Cahoon et al., 2021; Dearing et al., 2012; Leyva et al., 2021; Missall et al., 2017; Purpura et al., 2020; Zippert & Rittle-Johnson, 2020) to further explore the relations between frequency of home math activities and children's math skills. We use a CFA approach to confirm our hypothesis that home math activities can be operationalized by the math subdomains being targeted and explore whether this is a worthwhile framework to consider for the home math environment field. This study aimed to address the following research questions:

1. Is there a factor structure of frequency of home math activities in which each factor corresponds to a math subdomain?

We hypothesized that a factor structure with factors corresponding to each math subdomain would fit the data, based on previous research suggesting the presence of some factors of home math activities targeting specific math subdomains (Cahoon et al., 2021; Purpura et al., 2020).

2. Does this factor structure of frequency of home math activities relate to children's math skills in the same subdomains?

We hypothesized that positive associations would be found between frequency of home math activities and children's math skills in the same subdomain based on previous research suggesting that frequency of home math activities targeting these subdomains is positively associated with children's math skills (Napoli & Purpura, 2018; Purpura et al., 2020; Segers et al., 2015; Skwarchuk et al., 2014).

Method

Participants

This study used data from a larger longitudinal study of the effects of a math intervention on parent-child math conversations during daily family routines. All data included in the current study were collected prior to the start of the intervention. Participants for this study were 78 parent-child dyads. Children ranged from 48 to 60 months (M^{Age} = 53.20 months, SD = 3.43; 45% female) and parents identified themselves as the primary caregiver of the child. Ninety-six percent of parents were mothers, 86% were White, and 87% had at least a four-year college degree. Dyads were recruited via an institutional online research platform and the Children Helping Science online research platform, flyers distributed in preschools, social media advertising, and word of mouth. To be eligible, dyads had to have a child who was four years old at the start of the study and did not have an intellectual or learning disability. Parents also had to live in the United States, speak, read, and write English fluently, and be comfortable being recorded on a videoconference call with their child. All parents gave written informed consent as approved by the local Institutional Review Board prior to the start of any research activities. The sample size of the current study was limited by the decisions made for the larger study, which involved more measures and an intervention across several timepoints and was designed as a pilot study.

Measures and Procedures

Parents were emailed a link to complete an online survey about their demographic information (e.g., child age and sex and parents' education) and frequency of home math activities (see below for more details). Around five days after the survey link was sent to parents, dyads took part in a videoconference call session during which the child completed math assessments. If the survey was not completed at the time of the videoconference call, parents received a reminder. After a week and a half without completion, survey data were considered missing.

Home Math Activities

The home math activities survey included 30 items in which parents reported on the frequency with which they engaged in a series of math activities with their child during a typical week (see Table 1 for list of survey items). The scale included the following four options: 1 (not at all), 2 (once per week), 3 (several times a week), 4 (every day). Of the 30 items, five were selected to capture counting and cardinality (e.g., "count out money"), seven items to capture comparison (e.g., "use terms 'more' and 'less'"), two items to capture number identification (e.g., "identifying names of written numbers"), six items to capture addition and subtraction (e.g., "add and subtract using objects"), and four items to capture patterning (e.g., "create simple patterns"). The remaining six items described activities that could incorporate multiple subdomains (e.g., "read number storybooks"). For each item, parents could also select an option for "my child is too old/young for this activity." Thirty-three percent of parents responded in this way to at least one of the items used in the study and no parent selected this option for more than nine items.

The items in this survey were compiled from a series of previous studies (Hart et al., 2016; LeFevre et al., 2009; Missall et al., 2017; Napoli & Purpura, 2018; Purpura et al., 2020; Segers et al., 2015; Zippert et al., 2020). The authors reviewed 24 manuscripts that described surveys of home math activities for preschool-aged children and identified items that were used across multiple studies. Because the current study was a part of a larger study on the development of a family math intervention targeting counting and cardinality, comparison, number identification, addition and subtraction, and patterning, items were selected to target these specific math subdomains. The number identification subdomain only included two items because there were fewer items and less variability in items for this subdomain across studies compared to the other math subdomains.

Math Assessments

Children's math skills were assessed using two measures. The Preschool Early Numeracy Scale (Purpura & Lonigan, 2015) was used to measure children's skills in counting and cardinality, comparison, number identification, and addition and subtraction. There were 18 total items administered across four subscales: One-to-One Counting/Cardinality (five items), Set Comparison (four items), Numeral Identification (five items), and Story Problems (four items). Items administered were a subset of the items in this measure and the subscales chosen were a subset of the subscales available in this measure. In the One-to-One Counting/Cardinality subscale, children were shown three sets of six to 18 dots and asked to count the dots, then identify how many dots there were. In the Set Comparison subscale, children were shown four sets of dots, each set with zero to 13 dots. Children were asked to indicate which set had the most or least dots. In the Numeral Identification subscale, children were shown three single- and two double-digit numbers less than 20 and were asked what the number was. In the Story Problems subscale, children were told a verbal story involving a simple addition or subtraction problem (two addition and two subtraction) with numbers less than four and were asked to provide the answer. There were two similar forms for the measure and participants were assessed with all 18 items from one of the two forms. There was moderate to high scale reliability for all math subdomains (counting and cardinality: α = .83; comparison: α = .64; number identification: α = .79; addition and subtraction: α = .54). Percent correct for the items in each subdomain was calculated and used in analyses.

The Early Patterning Assessment (Rittle-Johnson et al., 2020) was used to measure children's patterning skills. A subset of six items was used to assess children's ability to recognize and complete patterns. Children were shown two items with a series of colored squares and asked whether or not the series made a pattern, two patterns with a missing item in the series and asked to identify what object is missing, and two patterns with several missing items at the end and asked to identify what items would come next. There was low scale reliability for this subset of items (α = .31). This reliability is lower than what was found for the full set of items in this measure (α = .73; Kaufman et al., 2021) possibly due to the small number of items used in the current study. Percent correct for the patterning subdomain was calculated and used in analyses.

These assessments were adapted for virtual administration. The researcher shared images from their screen during the videoconference session and for the multiple-choice items, prompted the child to say the letter (A-C or A-D depending on the number of possible responses) located above the answer the child wanted to select. If the child had trouble recognizing these letters, the researcher pointed to each picture with their mouse and asked, "Is it this one?" and the child answered yes or no. The parent was asked to be present for these assessments to support technical difficulties but was asked not to provide any feedback or support to the child during these assessments. If parents attempted to respond to the child in any way during the assessment, they were reminded by the researcher that the goal of the assessment was to see what the child knows on their own.

Data Analytic Plan

To address the first research question, two CFAs were conducted in RStudio on the home math activities data. The first model included one factor with all items for which at least 50% of parents report that they did more often than never (cf. Hart et al., 2016; Purpura et al., 2020) and the second model included six factors, one factor for each of the math subdomains (counting and cardinality, comparison, number identification, addition and subtraction, patterning) and a sixth ambiguous subdomain factor for items that could incorporate multiple subdomains. Given the categorical nature of data, the CFAs included indications that the data were ordered and that the model should be based on polychoric correlations.

Model fit was evaluated using chi-square (χ^2), comparative fit index (CFI), Tucker-Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root-mean-square residual (SRMR) suggested by Hu and Bentler (1999). After the six-factor CFA was conducted, modification indices were used to improve model fit and items were removed with a factor loading of less than .30, which is the recommended cutoff for item deletion (Tavakol & Wetzel, 2020).

To address the second research question, two SEMs were conducted testing for associations with children's math skills in each subdomain with the factor made up of home math activities items in the same subdomain. For example, the factor of home math activities items about comparison was associated with children's skills in comparison, the factor of home math activities items about addition and subtraction was associated with children's skills in addition and subtraction, etc. The first SEM included just the factors and outcomes, while the second SEM controlled for child age (in months), child sex (coded as dummy variable with reference group female) and parents' education (coded as a dummy variable with reference group 4-year college degree or higher). Only pathways from home math activities to math skills in the same subdomain were examined for parsimony given the limited sample.

There were no missing data on the math skills assessments or home math activities survey, but there were some items on the home math activities survey for which parents selected the option for "my child is too old/young for this activity." Following prior research (LeFevre et al., 2009), these data were recoded as "1", demonstrating they did not occur, given that this response suggested that the parent and child did not engage in the activity.

Results

Descriptive statistics for frequency of home math activities are presented in Table 1 and descriptive statistics for child math skills in each of the five math subdomains are presented in Table 2. Pearson correlations between the final latent factors and the outcome variables (child math skills in the five math subdomains) are presented in Table 3. Distributions for the items used in the study can be found in Table S1 in the Online Supplementary Materials (see McGregor Reiner et al., 2025S). Five items (3, 5, 8, 27, 28) were removed as more than 50% of parents reported that they never did these activities with their child.

Testing the Factor Structure of Home Math Activities

The first goal of the current study was to examine the factor structure of home math activities by math subdomain. First, a one-factor CFA was performed with all remaining survey items (25) loading onto a single general home math activities factor. The criterion-based fit statistics (i.e., CFI, TLI, RMSEA, and SRMR) suggested that this model demonstrated adequate fit; $\chi^2(275) = 509.276$ ($p < .001$), RMSEA = .11 (90% CI [.09, .12]), CFI = .84, TLI = .83, SRMR = .15. Factor loadings ranged from weak to strong (range = 0.11–0.93) and can be found in Table 1. A second CFA was performed with six factors, one for each of the math subdomains and the final factor for activities that could incorporate multiple subdomains. This model demonstrated adequate fit; $\chi^2(260) = 341.470$ ($p = .001$), RMSEA = .06 (90% CI [.04, .08]), CFI = .95, TLI = .94, SRMR = .11. One item had a factor loading of less than 0.30 (Item 29) and was dropped from the model. Fit statistics for the model with this item removed were similarly acceptable, $\chi^2(237) = 309.535$ ($p = .001$), RMSEA = .06 (90% CI [.04, .08]), CFI = .95, TLI = .94, SRMR = .11. Finally, we examined modification indices for this model and identified one covariance with a much larger modification index than all other covariances (Items 13 and 14). Fit statistics for the model with this covariance included were $\chi^2(236) = 289.859$ ($p = .010$), RMSEA = .05 (90% CI [.03, .08], CFI = .96, TLI = .96, SRMR = .10. A chi-square difference test indicated that this model was significantly better fitting than the previous model ($p < .001$), so this model was chosen as the final model. Factor loadings for this final measurement model can be found in Table 1.

Relations Between Home Math Activities and Child Math Skills

For the second goal of the study, a SEM was performed with associations between the home math activities factors and children's math skills in each subdomain. Fit statistics indicated that this model had good fit; $\chi^2(351) = 409.048$ ($p = .018$), RMSEA = .05 (90% CI [.02, .07]), CFI = .96, TLI = .95, SRMR = .10. This model is illustrated in Figure 1. This model shows that the factor for home math activities in each of the math subdomains was positively and significantly associated with child math skills in that subdomain for all subdomains (all ps < .05) except number identification ($p = .181$).

Given this strong model fit, a second SEM was performed to include the covariates of child age, child gender, and parent education. Surprisingly, fit indices indicated that this model had poor fit; $\chi^2(454) = 1066.756$ ($p < .001$), RMSEA = .13 (90% CI [.12, .14]), CFI = .70, TLI = .72, SRMR = .21. Follow-up analyses with each of the covariates showed that child age was driving this large drop in model fit, suggesting measurement non-invariance across child age. To better understand this result, we applied a mean split to the sample by child age (53.2 months), such that the younger sample contained $n = 41$ participants, and the older sample contained $n = 37$.

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Table 1

Descriptive Statistics and Factor Loadings for Home Math Activity Items

#	Item	% Responding Never	*M*	*SD*	General Home Math Factor Loadings	Counting and Cardinality Factor Loadings	Comparison Factor Loadings	Number Identification Factor Loadings	Addition and Subtraction Factor Loadings	Patterning Factor Loadings	Ambiguous Subdomain Factor Loadings
Counting and Cardinality Factor											
1	Count objects	1.28	3.58	0.59	0.23	0.59	–	–	–	–	–
2	Count down (10, 9, 8, 7…)	8.97	2.71	0.87	0.32	0.73	–	–	–	–	–
4	Count using his/her fingers	8.97	3.00	0.94	0.19	0.44	–	–	–	–	–
Comparison Factor											
7	Identify numbers as more or less (e.g., 7 is more than 4)	15.38	2.56	0.96	0.65	–	0.72	–	–	–	–
13	Compare groups of objects to identify more or less or same/equal	10.26	2.65	0.91	0.65	–	0.64	–	–	–	–
14	Use terms "more" and "less"	5.13	3.22	0.89	0.62	–	0.59	–	–	–	–
20	Create equal-sized groups from a larger group (e.g., sharing snacks fairly)	29.49	2.24	1.05	0.75	–	0.83	–	–	–	–
22	See that one object is bigger or smaller than another by directly comparing them	7.69	2.69	0.86	0.61	–	0.68	–	–	–	–
23	Use comparative terms like bigger, longer, taller, and heavier	1.28	3.51	0.66	0.57	–	0.64	–	–	–	–
Number Identification Factor											
6	Identifying names of written numbers	6.41	3.12	0.87	0.36	–	–	0.62	–	–	–
9	Note numbers on signs when driving/walking	8.97	2.97	0.94	0.53	–	–	0.99	–	–	–
Addition and Subtraction Factor											
17	Learn simple sums (i.e., 2+2 = 4)	21.79	2.42	1.01	0.74	–	–	–	0.81	–	–
18	Add and subtract using objects	24.36	2.26	0.95	0.84	–	–	–	0.91	–	–
19	Recognize how parts make a whole	32.05	2.00	0.87	0.71	–	–	–	0.78	–	–
21	Practice adding or taking away from an amount to create more or less	30.77	2.21	1.01	0.80	–	–	–	0.86	–	–
Patterning Factor											
24	Recognize patterns or repeating sequences of things in their everyday settings and activities	12.82	2.78	0.98	0.68	–	–	–	–	0.79	–
25	Duplicate simple patterns (e.g., looking at grapes in a red, green, red, green pattern and using two different colored cheese cubes to make the same alternating pattern)	37.18	2.09	1.02	0.82	–	–	–	–	0.89	–
26	Create simple patterns	19.23	2.32	0.95	0.92	–	–	–	–	0.99	–
30	Discuss patterns in days of the week, months of the year, or seasons	23.08	2.29	0.90	0.41	–	–	–	–	0.49	–
Ambiguous Subdomain Factor											
10	Measure ingredients when cooking	14.10	2.31	0.76	0.41	–	–	–	–	–	0.48
11	Use calendars and dates	21.79	2.64	1.08	0.46	–	–	–	–	–	0.55
12	Use numbers in reference to temperature, time, and dates	5.13	3.29	0.87	0.29	–	–	–	–	–	0.32
15	Read number storybooks	8.97	2.77	0.84	0.33	–	–	–	–	–	0.39
16	Play games in the car that involve math	32.05	2.03	0.90	0.61	–	–	–	–	–	0.69

#	Item	% Responding Never	*M*	*SD*	General Home Math Factor Loadings	Counting and Cardinality Factor Loadings	Comparison Factor Loadings	Number Identification Factor Loadings	Addition and Subtraction Factor Loadings	Patterning Factor Loadings	Ambiguous Subdomain Factor Loadings
Items removed for high frequency of not occurring											
3	Count by something other than 1s, like 2s, 5s, or 10s	55.13	1.71	0.91	–	–	–	–	–	–	–
5	Counting out money	61.54	1.44	0.59	–	–	–	–	–	–	–
8	Estimate a small number for small groups and a large number for large groups (e.g., estimating 6 for a small group of rocks and 30 for a large group of rocks)	51.28	1.81	0.95	–	–	–	–	–	–	–
27	Add and subtract to 10	50.00	1.85	1.01	–	–	–	–	–	–	–
28	Add and subtract to 20	80.77	1.37	0.85	–	–	–	–	–	–	–
Item removed for low factor loading											
29	Play computer games, apps or visit interactive websites that include number games	30.77	2.24	0.98	0.11	–	–	–	–	–	–

Note. Home math activities are measured on a 4-point Likert scale, with 1 representing “not at all,” 2 representing “once a week,” 3 representing “several times a week,” and 4 representing “every day.”

Table 2

Descriptive Statistics for Subdomains of Child Math Skills

Child Math Skills	*M*	*SD*	Range
Overall	57.91	20.44	16.67 – 100
Counting and Cardinality	54.62	37.13	0 – 100
Comparison	69.55	31.12	0 – 100
Number Identification	65.90	31.93	0 – 100
Addition and Subtraction	50.64	32.73	0 – 100
Patterning	51.07	22.53	16.67 – 100

Note. Child math skills are measured as percent correct.

Table 3

Correlations Between Home Math Activities Factors and Child Math Skills

Subdomain	1	2	3	4	5	6	7	8	9	10
Home Math Activities										
1. Counting and Cardinality	–									
2. Comparison	0.15	–								
3. Number Identification	0.38***	0.25*	–							
4. Addition and Subtraction	0.21†	0.72***	0.22†	–						
5. Patterning	0.16	0.42***	0.42***	0.47***	–					
Child Math Skills										
6. Counting and Cardinality	0.20†	0.14	0.18	0.30**	0.21†	–				
7. Comparison	-0.17	0.39***	-0.04	0.34**	0.10	0.35**	–			
8. Number Identification	0.04	-0.01	0.09	0.26*	0.12	0.50***	0.39***	–		
9. Addition and Subtraction	-0.08	0.22†	-0.03	0.43***	0.14	0.23*	0.41***	0.25*	–	
10. Patterning	-0.01	0.10	0.03	0.28*	0.25*	0.13	0.21†	0.18	0.34**	–

†p < .10. *p < .05. **p < .01. ***p < .001.

We then performed two separate models, examining the final CFA model with both samples. This approach was chosen rather than a single multi-group SEM because of skewness in the endorsement of the options for some items between the two groups. Fit indices indicated that the model fit the data in the older sample well; $\chi^2(259) = 273.313$ (p = .259), RMSEA = .04 (90% CI [.00, .08]), CFI = .98, TLI = .98, SRMR = .12. However, the CFA model performed in the younger sample did not converge, suggesting it does not represent the data in this sample well. Additional follow-up ANOVAs revealed some differences in the frequency of parent report of home math activities across these two samples. Parents of children in the older sample reported significantly higher frequencies of Item 18 (Add and subtract using objects), marginally significantly higher frequencies of Items 7 (Identify numbers as more or less, e.g., 7 is more than 4) and 25 (Duplicate simple patterns, e.g., looking at grapes in a red, green, red, green pattern and using two different colored cheese cubes to make the same alternating pattern), and marginally significantly lower frequencies of Item 1 (Count objects) than parents of children in the younger sample. See Table 4 for results of these analyses for these four items.

Table 4

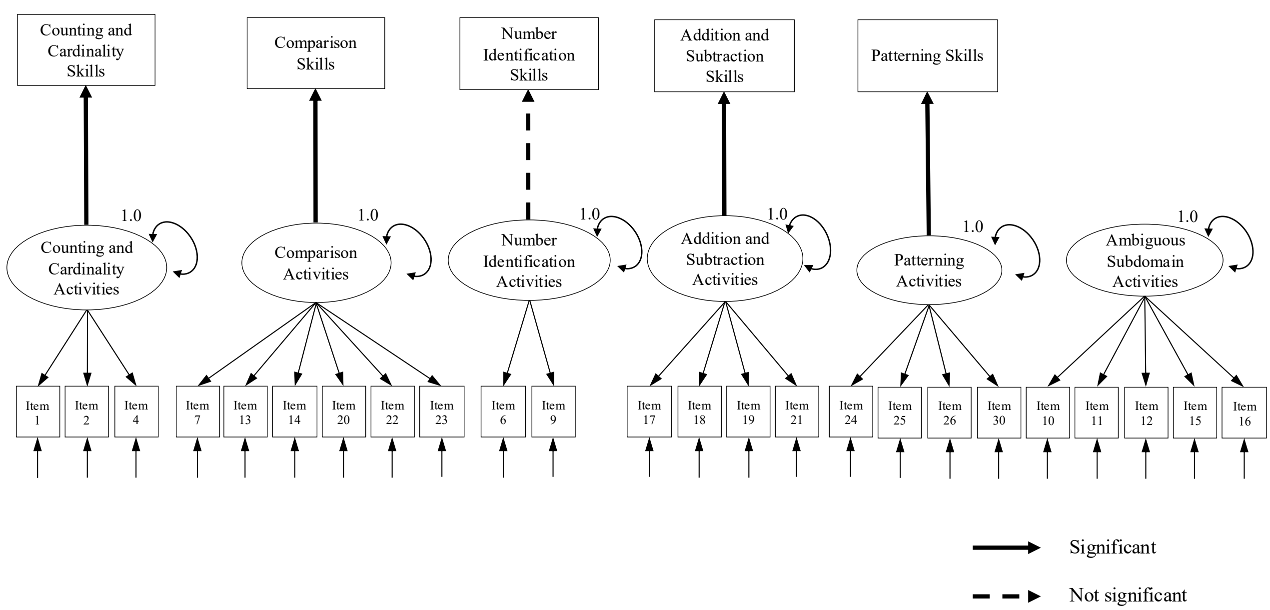
Descriptive Statistics for Home Math Activities by Age Group With Significant Differences

		Younger Sample		Older Sample			
#	Item	*M*	*SD*	*M*	*SD*	*F*(3,74)	*p*
1	Count objects	3.71	0.51	3.43	0.65	2.47	.069
7	Identify numbers as more or less, e.g., 7 is more than 4	2.37	0.86	2.78	1.03	2.35	.079
18	Add and subtract using objects	1.98	0.94	2.57	0.87	3.20	.028
25	Duplicate simple patterns, e.g., looking at grapes in a red, green, red, green pattern and using two different colored cheese cubes to make the same alternating pattern	2.02	1.13	2.16	0.90	2.28	.087

Note. Home math activities are measured on a 4-point Likert scale, with 1 representing "not at all," 2 representing "once a week," 3 representing "several times a week," and 4 representing "every day."

Figure 1

Final Model for Home Math Activities and Child Math Skills



Note. Solid lines represent significant associations, and dotted lines represent non-significant associations.

Discussion

The current study examined the factor structure of home math activities by math subdomain to determine whether frequency of home math activities was associated with child math skills within subdomains. We found that the factor model by math subdomain was a good fit and higher frequency of home math activities in counting and cardinality, comparison, addition and subtraction, and patterning positively related to math skills in the same subdomains. In addition, we found that this factor structure was a better fit for older four-year-old children but may not represent the experiences of younger four-year-old children. We built on previous research to suggest that this operationalization,

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combined with latent variable methods that identify constructs based on factor analyses, is a useful interpretation of the home math environment.

Our hypothesized factor structure fit the data well: all but one of the items loaded to an acceptable degree onto the factor for the specific math subdomain. While some studies have examined frequencies of activities targeting specific math subdomains (Leyva et al., 2021; Missall et al., 2017) and others have used latent variable approaches to identify constructs based on type of activity and math subdomain (Cahoon et al., 2021; Hart et al., 2016; Purpura et al., 2020), the current study was the first to use confirmatory factor analysis to focus exclusively on math subdomains. By emphasizing the type of math skill that the activities are targeting rather than the type of activity, we can capture how parents are using math concepts with their children during these activities. Our model suggests that the five math subdomains (counting and cardinality, comparison, number identification, addition and subtraction, and patterning) do make up separate factors, which furthers our understanding of how to operationalize home math activities. More work is needed to understand if this operationalization replicates in other samples and how it might be influenced by additional math subdomains such as spatial activities, which have been examined as a part of home math activity factor structures across several studies (Dearing et al., 2012; Hart et al., 2016; Purpura et al., 2020).

We found positive associations between home math activity factors and children's math skills in the same subdomain for counting and cardinality, comparison, addition and subtraction, and patterning. Some prior studies have found positive associations between global measures of math activities and children's math skills; these global measures target numeracy activities including counting and cardinality (Hart et al., 2016; Manolitsis et al., 2013; Napoli & Purpura, 2018), comparison (Napoli & Purpura, 2018), and addition and subtraction (Purpura et al., 2020; Skwarchuk et al., 2014). To our knowledge, we are the first to find associations between patterning home math activities and children's patterning skills. However, these results need to be treated with caution because of the low reliability for the patterning skills measure in this sample. More research is needed with a more robust measure of children's patterning skills to replicate this result.

We did not find significant associations between frequency of number identification home math activities and children's number identification skills. In addition, number identification was the only subdomain in which we did not find at least marginally significant positive correlations between the home math activities and child math skills in the same subdomain. There were several potential reasons why we did not find this association. First, there may have been a ceiling effect for the items in the number identification factor, as the two items making up that factor are some of the most highly endorsed in the questionnaire. It is possible that with a larger sample or additional items to contribute additional variance to this factor, we would have seen an association. Second, there is little work examining predictors of children's number identification skills, so it is difficult to know whether these results are specific to the current study. One study that measured a series of preliteracy and math skills in preschool children found that preliteracy skills such as letter identification predicted number identification skills in preschool (Chu et al., 2016). While this study did not examine home math activities, these results suggest that other skills may also play a role in children's development of this early math skill. Third, the number identification home math activities used in the current study (i.e., identifying names of written numbers and noting numbers on signs while driving/walking) did not specify which types of numbers were being discussed. The number identification math skills items on the other hand assessed both single- and double-digit knowledge, so parents may be engaging in activities with single-digit numbers but not with double digit numbers. Four-year-old children often have well-developed skills in the identification of single-digit numbers but are still developing their understanding of double-digit numbers (Litkowski et al., 2020). This conclusion is supported by the current study, as 72-95% of children correctly identified the three single-digit numbers, while only 41% correctly identified each of the two double-digit numbers. Asking parents about how frequently they identify single- versus double-digit numbers with their child could provide additional support for understanding what types of numbers parents discuss and how these activities relate to children's number identification skills.

Surprisingly, we found that the measurement model was a strong fit for children from 53-60 months, while it did not fit for children from 48–53 months. In addition, parents of the older children were less likely to report counting objects and more likely to report adding and subtracting using objects, identifying numbers as more or less, and duplicating simple patterns. This result is interesting given that previous studies examining factor structures of home math activities have used larger age ranges than the current study (3–8 years in Hart et al., 2016; 3–6 years in Purpura et al., 2020). One possible explanation for these results is the timing of the study as it pertains to the start of the academic school year and kindergarten cutoffs in the United States. Kindergarten entry and the beginning of formal education is typically marked by a child turning five years old by September, though exact cutoff dates can differ by state and school. Given that data collection for the current study lasted from March to September of a single calendar year, most of the children who were at least 53 months when they began the study turned five years old in time to begin kindergarten the upcoming fall. However, children who were younger than 53 months during this time had recently turned four and would likely take one more year before beginning kindergarten. Parents of children who are newly four may be more focused on introductory math concepts such as counting, while parents of children who are preparing for kindergarten may be motivated to focus on more complex math concepts with their child. In addition, data were collected during the COVID-19 pandemic, during which time parents of older four-year-olds may have felt increased pressure to prepare their children for kindergarten as preschool attendance was irregular or non-existent for many children. A recent study with parents of 1- to 6-year-olds found large variability in how appropriate parents viewed different math activities for their child by age (Ehrman et al., 2023). The measurement non-invariance of the model in the current study relative to child age suggests that an operationalization of home math activities focused on the math subdomain may be most appropriate for children preparing for formal education, but less relevant for younger preschool-aged children whose parents may not yet recognize the full breath of math topics to discuss with their child.

In considering the implications of this study, it is important to acknowledge that, while sample size recommendations for SEM are not “one size fits all” and depend on the number of factors and indicators (Wolf et al., 2013), the sample size of the current study was small compared to general recommendations for SEM analyses. As a result, the SRMR value for the final measurement model is slightly higher than the recommended cutoff of .08 (Hu & Bentler, 1999). SRMR values are strongly influenced by sample size and distribution, suggesting that a high SRMR value despite the good fit indicated from the remaining indices is likely due to the small sample size of the current study. The intention of this study is not to claim that operationalizing home math activities based on math subdomain should replace existing frameworks that have been extensively studied with much larger samples. However, we do see this study as an important first step to proposing an additional approach to considering the home math environment for preschool-aged children and their parents. Future research should build on this initial exploration and continue to more deeply examine the role of math subdomains in operationalizing home math activities.

Limitations

The generalizability of the present study is limited because the sample included mostly White and highly educated mothers and their children in the United States. Furthermore, the activities included in our survey may reflect culturally relevant values about learning at home that are held by middle-class White families in the US but may not be held by families from other socioeconomic, ethnic/racial, and cultural backgrounds. These data were collected concurrently, so conclusions can only be made about associations between frequency of home math activities and children’s math skills from one moment in time. It is also not possible to conclude directionality of these relations from the data in the current study. Future longitudinal studies might explore the associations between frequency of home math activities per subdomain and children’s math skills over time. Finally, this study focused on five subdomains of early math development: counting and cardinality, comparison, number identification, addition and subtraction, and patterning. We did not include other math subdomains, such as spatial skills, geometry, and measurement. In the future, it would be important to include these subdomains because parents may be engaging in activities with their child around these topics and because they are important for preschoolers’ math development (Dearing et al., 2012; Hart et al., 2016; Hornburg et al., 2021).

Conclusion

Despite these limitations, the current study suggests a framework for the home math activities of parents and their four-year-old children by using latent variable approaches to examine associations between home math activities and child math skills by subdomains. The home math environment is complex and nuanced, and these results further expand our understanding of what occurs between parents and children at home as children learn math. Though previous frameworks of the home math environment may also be valuable for understanding how parents support preschool children's math development, the current study suggests an additional approach to consider when operationalizing home math activities in young children which may provide the groundwork for future parent-focused intervention. Further research is needed to expand the use of this framework and explore its application in new contexts and samples, but this study contributes an important step in deepening our understanding of children's early math environment.

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Competing Interests: The authors have declared that no competing interests exist.

Data Availability: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Supplementary Materials

The Supplementary Materials contain histograms of the distributions of frequency ratings for the home math activities items (see McGregor Reiner et al., 2025S).

Index of Supplementary Materials

McGregor Reiner, R., Leyva, D., Ribner, A., & Libertus, M. E. (2025S). *Supplementary materials to "Examining a factor structure of home math activities by math subdomain with associations to children's math skills"* [Histograms]. PsychOpen GOLD. https://doi.org/10.23668/psycharchives.21082

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