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Young girls' arithmetic and spatial skills: The distal and proximal roles of family socioeconomics and home learning experiences

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ABSTRACT

The present study addressed girls' ($N = 127$) early numerical and spatial reasoning skills, within the context of a critical environment in which these cognitive skills develop, namely their homes. Specifically, proximal links between distal family socioeconomic conditions and first-grade girls' arithmetic and spatial skills were examined (mean age = 6.72 years; SD = .34). The proximal roles of two factors were considered: the general learning characteristics of girls' homes, and the kinds of math and spatial learning activities in which girls participated. General quality of the home learning environment and specific math activities mediated the relation between family socioeconomics and girls' arithmetic skills. In contrast, socioeconomics and home learning experiences were related to girls' spatial skills indirectly only through their verbal skills; spatial activities were *not* proximal predictors of spatial skills. For both arithmetic and spatial skills, mothers' spatial skills were a strong predictor. Future research and intervention implications of these findings are discussed.

Arithmetic and spatial skills at school entry may have long-term consequences for children's life chances. Being underprepared for mathematics at the outset of schooling is associated with persistent underachievement in both math and reading, decreased odds of graduating from high school, and reduced earnings in adulthood (e.g., Currie & Thomas, 2000; Duncan et al., 2007; Feinstein & Bynner, 2004). Further, in longitudinal studies, early spatial skills predict long-term math performance (Krajewski & Ennemoser, 2009; Wolfgang, Stannard, & Jones, 2001). Spatial skills have also been shown to be particularly important for later success in science, technology, engineering, and math (STEM) fields (Wai, Lubinski, & Benbow, 2009).

Recent meta-analyses indicate a historical trend toward shrinking differences and increasing similarities in the cognitive performance of boys and girls (Lindberg, Hyde, Linn, & Petersen, 2010). Yet, some gender differences seem to persist. In a review of gender research for the National Academies, Halpern (2006) summarized the findings, "Although there is much overlap in the female and male distributions, on average, females excel on many memory tasks including memory for objects and location, episodic memory, reading literacy, speech fluency, and writing. Males excel at visuospatial transformations, especially mental rotation, science achievement, mathematics tests that are not tied to a specified curriculum. . ." (p. 113).

For mathematics, it was previously thought that there is a reversal of gender differences in performance–with girls outperforming boys prior to first grade (Ginsburg & Baroody, 2003), and then boys outperforming girls during elementary school and later (Penner & Paret, 2008). These conclusions were primarily based on cross-sectional studies, comparing different samples of children at different ages (Gibbs, 2010). Recently, the findings from a national longitudinal study have been used to follow individual children's math performance from early to middle childhood and beyond (Gibbs, 2010; Robinson & Lubienski, 2011). Using this longitudinal sample, Gibbs (2010) did not find a reversal in the direction of gender differences in mathematics. Instead, he found that across early childhood, girls outperformed boys on counting, number, shape identification, and relative size problems, but boys outperformed girls on simple arithmetic problems using addition and subtraction. This advantage in arithmetic for boys persisted into middle childhood on multiplication and division problems.

Nevertheless, it should be pointed out that gender differences in mathematics are smaller than for spatial problems, which show large effect sizes favoring males. Gender differences in spatial skills are particularly evident for tasks involving mentally rotating and transforming objects in 3-d space (Halpern et al., 2007; Johnson & Meade, 1987; Nuttall, Casey, & Pezaris, 2005). In fact, these spatial skills differences have been shown to be the largest and most consistent of all cognitive gender differences (Halpern et al., 2007).

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One reason for spatial skill differences may be the types of strategies boys and girls use to solve these problems. On average, females tend to use less efficient verbal, analytical strategies that result in a more piecemeal mental rotation process; in contrast, males are more likely to use a spatial, holistic strategy in which whole objects are mentally rotated through space (Janssen & Geiser, 2010; Jordan, Wüstenberg, Heinze, Peters, & Jäncke, 2002; Pezaris & Casey, 1991; Schultz, 1991). Yet, even more so than for boys, spatial skills are important for girls' math problem solving (Battista, 1990; Carr, Hettinger, Steiner, Kyser, & Biddlecomb, 2008; Casey, Nuttall, & Pezaris, 1997; Fennema & Tartre, 1985; Friedman, 1995; LeFevre et al., 2010).

There is evidence that gender differences in spatial skills begin very early and across a wide variety of tasks. Studies with children as young as four and five years of age have shown a male advantage on 2- and 3-dimensional mental rotation tasks as well as other types of mental transformations (Casey et al., 2008; Cronin, 1967; Levine, Huttenlocher, Taylor, & Langrock, 1999; McGuinness & Morley, 1991). In a review of this literature, Levine et al. (1999) concluded that gender differences in young children have been observed across a wide range of spatial tasks including: spatial visualization tasks, mazes, part–whole relations puzzles, map reading, and 2-dimensional mental rotation tasks.

1. A different approach: studying factors predicting individual differences within girls

Comparative research has been useful for understanding differences and similarities between genders. This focus, however, has left an absence of work on the nuances of development *within* genders. We propose that it is critical to make a shift in the field toward gaining greater understanding of individual differences within the genders. Within-group study of disadvantaged groups is important for uncovering factors that may mitigate that disadvantage. Understanding individual differences within the genders is one key to understanding how to promote the achievement of those who demonstrate cognitive disadvantage.

A case in point is the need for further understanding of variability in girls' arithmetic and spatial skills. Although both girls and boys demonstrate relative advantages in various cognitive domains, arithmetic and spatial skills are two areas in which girls, on average, appear at risk to underperform relative to boys (e.g., Gibbs, 2010; Levine et al., 1999). By focusing on variability among girls, we aimed to provide a nuanced account of developmental mechanisms that may promote their arithmetic and spatial skills – identifying within-gender proximal mechanisms that account for why some girls perform better than others is a means for identifying targets for intervention. In the present study, we give special attention among girls to a critical environment in which their cognitive skills develop, namely their homes.

Specifically, we examined an empirical model linking distal family socioeconomic conditions with girls' arithmetic and spatial achievement. In this model, we considered the proximal mediating roles of two factors: the general learning characteristics of girls' homes, and the kinds of arithmetic and spatial learning activities in which girls participate. By doing so, we united two previously distinct empirical literatures: (1) studies examining the *general* quality of children's home learning environments as a mediator of associations between family socioeconomics and arithmetic/spatial performance; and (2) studies examining the *specific* effects of early math and spatial experiences on math/spatial performance.

2. From the home learning environment to child achievement

With child achievement dependent on extensive investments of time, energy, and material resources, children's homes generally serve as the first and most enduring environment in which these investments occur (Dearing & Tang, 2010). Indeed, both the physical and psychosocial elements of home contexts are relevant for child learning (Dearing & Tang, 2010). More specifically, in considering the home as a learning environment, at least two types of family investment are crucial: (1) providing learning materials that stimulate cognitive growth, and (2) parent engagement in enriching, learning-related activities with their children (for reviews, see Bradley & Corwyn, 2004; Brooks-Gunn & Markman, 2005; Dearing & Tang, 2010). Overwhelmingly, however, research on home learning environments has been focused on literacy enrichment (e.g., children's access to books and other print materials, parent–child talk, and reading activities in the home). There is much less evidence linking mathematical enrichment in the home with child math performance (Dearing & Tang, 2010).

Yet, the work of Lemelin and colleagues suggests this is an area of study worth pursuing, particularly for early math and spatial skill development (Lemelin et al., 2007). Using a genetically-sensitive design, these authors found that environment explained 100% of the variance in 5-year-old twins' spatial school readiness skills and 66% of the variance in their numerical school readiness skills. The contributions of early environments outside the home (e.g., child care) not withstanding, these results indicate that the contributions of home environments to early math and spatial skills are likely substantial. As these authors noted, research is now needed to precisely identify the proximal processes at work. That is the primary purpose of the present study.

2.1. The role of socioeconomics: exceptional consequences for girls?

The home environments of children living in families with low income and little education are, on average, characterized by deprivation and disadvantage. Low income and low education can constrain: (a) access to resources such as books, art materials, puzzles, toys, games, and musical instruments, and (b) stimulating involvement from parents including, reading to them, attempting to interest them in activities or play with toys, discussing television programs they have watched together, encouraging hobbies, and teaching them school readiness concepts, such as the alphabet, numbers, colors, and shapes (e.g., Bradley, Corwyn, Pipes McAdoo, & García Coll, 2001; Davis-Kean, 2005; Hart & Risley, 1995; Hoff, 2003; Hoff-Ginsberg & Tardif, 1995). Despite these common constraints on investments in the home learning environment, researchers have highlighted ways that some low-income parents find to invest in their children's early education. Some parents, for example, take advantage of social and educational activities in neighborhood churches, and being involved at school (e.g., Dearing, Kreider, Simpkins, & Weiss, 2006; Jarrett, 1999; Johnson, Jang, Li, & Larson, 2000). Yet, low-income children in the most deprived homes with the lowest levels of cognitive stimulation appear least likely to receive these types of learning investments outside of their homes (e.g., Dearing, McCartney, & Taylor, 2009).

There is also evidence that socioeconomic disadvantage may exacerbate cognitive gender differences. Some researchers, for example, have found that gender gaps *favoring girls in literacy* are larger within the context of poverty (e.g., Entwisle, Alexander, & Olson, 1994). At the same time, gender gaps *favoring boys in mathematics* are most pronounced within disadvantaged schools (Ma, 2008). Further, girls who grow up in families of low socioeconomic status (SES) are more likely to demonstrate persistent low achievement on measures of general cognitive ability than are boys in this context (Feinstein & Bynner, 2004).

The exacerbating effect of SES on gender differences may be explained, in part, by low-SES parents (particularly fathers) investing more time in learning and play activities with their sons beginning in early childhood than with their daughters (Yeung & Glauber, 2008; Yeung, Sandberg, Davis-Kean, & Hoffreth, 2001). Relations between family SES and parents' educational expectations for their children also appear to differ for girls and boys: an experimental evaluation of an anti-poverty program demonstrated a greater positive impact of socioeconomic improvements – via wage supplements and subsidized health insurance – on parents' educational aspirations for young boys than for young girls (Huston et al., 2001). This program also demonstrated a positive impact on low-income boys', but not girls', increased participation in organized out-of-school activities (Huston et al., 2001).

3. From children's specific math and spatial experiences to achievement

LeFevre et al. (2009) demonstrated that children's arithmetic performance in the early school years was positively predicted by frequently engaging in home activities centered on numerical skills (e.g., board and card games involving counting, talking about numbers, using a calendar, playing with a calculator). There are also relevant experimental studies – in the laboratory or preschool classroom – demonstrating that engaging young children in an array of numerical activities (e.g., board games, books, computer games, and songs) improves math achievement (Griffin, 2004; Klein & Starkey, 2004). Indeed, playing board games that emphasize numerical skills improves low-income children's abilities to identify numbers, count, compare numerical magnitudes, and estimate positions on a number line (e.g., Ramani & Siegler, 2008; Siegler & Ramani, 2008). There is also increasing evidence of positive associations between math activities in the home (e.g., counting, counting objects, identifying numbers) and young children's math performance (Blevins-Knabe & Musun-Miller, 1996; Huntsinger, Jose, Larson, Krieg, & Shaligram, 2000; LeFevre, Clarke, & Stringer, 2002; LeFevre et al., 2010). Yet, parent instruction during laboratory tasks may be unrelated to math performance (Pan, Gauvain, Liu, & Cheng, 2006), and there is some evidence that literacy stimulation in the home may be more strongly related to numeracy skills in early childhood than is numeracy stimulation (Anders et al., in press; also see, Blevins-Knabe, Austin, Musun, Eddy, & Jones, 2000, for a report of null associations between math activities and math performance).

Research on spatial activities has also shown a relation between early spatial experiences and spatial performance. Among preschoolers, Serbin and Connor (1977, 1979) found a relation between "masculine play," which included play with blocks and other construction toys, and spatial visualization skills (which involves the multi-step processing and transformation of spatial information through mental manipulations). Further, in a longitudinal study of mother–child interactions in the home, toddlers' early play with puzzles predicted their mental rotation and mental transformation skills at preschool (Cannon, Levine, & Huttenlocher, 2007).

4. The present study

The goal of the present study was to identify factors that contribute to young girls' arithmetic and spatial performance and the distal-proximal pathways of association by which these factors operate. Specifically, we have taken a comprehensive approach to young girls' home environments and experiences, examining multiple factors simultaneously: (1) starting with distal SES factors (such as income level, mothers' education, and financial stress), (2) moving to the more proximal, but general environmental conditions within the home (such as parental investment of time and material resources), and (3) finally examining the types of specific math and spatial activities experienced by these young girls.

We predict that numerical and spatial activities will be the most proximally related predictors of math and spatial achievement at school entry for girls. That is, these activities will mediate the more distal effects of both general learning stimulation in the home and family socioeconomics. Following the lead of developmental theorists who have argued that domain-specific elements of the home environment are best understood in the context of domain-general elements of the home (.g., Bronfenbrenner & Morris, 1998; Darling & Steinberg, 1993; Parke, Buriel, & Damen, 1998), we expect that the general level of investment that families put into the learning environment of the home has an influence on the likelihood of girls engaging in domain-specific arithmetic- and spatial-learning activities in their homes. General stimulation in the home has been found to promote: (a) positive attitudes toward learning, (b) motivation, and (c) metacognitive reasoning (Dearing & Tang, 2010; Gottfried, Fleming, & Gottfried, 1998; Grolnick, Kurowski, & Gurland, 1999). In turn, we suspect that this intrinsic motivation, curiosity, and exploration fostered by high levels of general learning stimulation may increase the likelihood of girls seeking out domain-specific math activities. Moreover, parents who are invested in learning, more generally, likely have a greater propensity than other parents to invest their time and energy in arithmetic and spatial activities with their daughters. Thus, we hypothesize that girls with greater general home learning stimulation will be more likely than other girls to engage – independently and jointly with parents – in a variety of learning activities, including those that emphasize numerical and spatial reasoning (e.g., playing with a calculator and building with construction toys).

In the present study, we also considered the role of girls' verbal skills. Previous empirical work has demonstrated a relation between early verbal skills and both numerical and arithmetic performance, perhaps because verbal skills are central to acquiring numerical vocabulary (Kurdek & Sinclair, 2001; LeFevre et al., 2010). Further, girls tend to apply verbal problem-solving strategies when working on spatial tasks (Janssen & Geiser, 2010; Jordan et al., 2002; Pezaris & Casey, 1991), and verbal skills have been shown to predict spatial skills for young girls, but not for boys (Klein, Adi-Japha, & Hakak-Benizri, 2010). We expected, therefore, that verbal skills would proximally predict arithmetic and spatial skills, mediating more distal home environment and SES factors. Finally, we analyzed the contribution of maternal spatial skills to their daughters' arithmetic and spatial skills, with the expectation that mothers' abilities would have both direct and environmentally-mediated implications for girls' performance. Our overall hypothesized pattern of associations is displayed in Fig. 1.

5. Method

5.1. Sample

Participants were 127 first-grade girls – mean age of 6.72 years (SD = .34) – and their mothers. Girls were recruited from 27 regular education classrooms in two Northeastern public-school districts, excluding students with individualized education plans for disabilities. Girls whose mothers were English- or Spanish-speaking were included in the study, with four mothers reporting Spanish as their primary/preferred language. As a group, families lived in a wide range of socioeconomic conditions, with about 40% of the sample

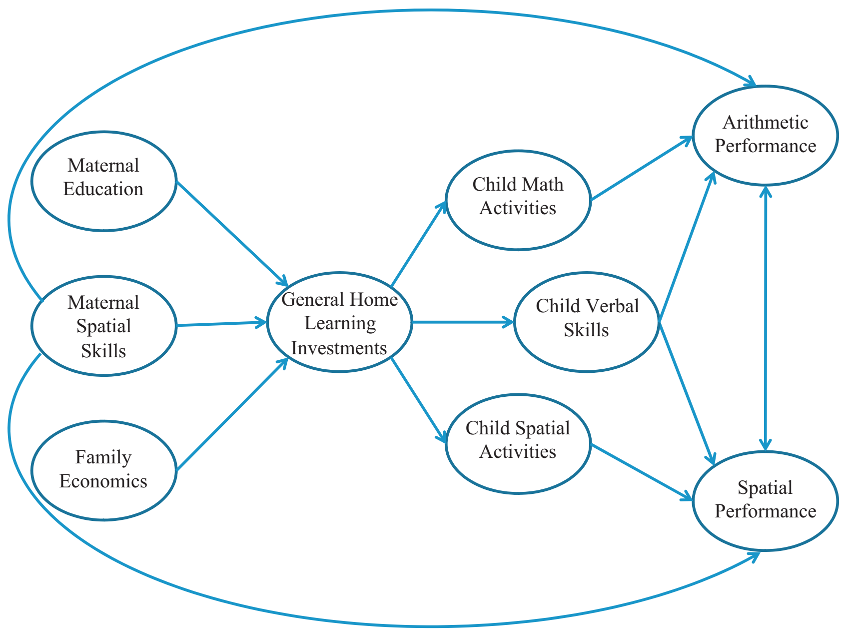

Fig. 1. Hypothesized model of direct and indirect associations linking home learning environments with girls' arithmetic and spatial performance.

having incomes less than 200% of the federal poverty threshold and about 40% having incomes greater than 450% of the poverty threshold. With regard to ethnicity/race, the sample was approximately 63% White, 12% Asian, 10% Latino, and 3% Black – of the remaining 12% of the sample, approximately 5% were multiracial and another 7% of mothers' reported their child's ethnicity/race as "other."

5.2. Procedure

Telephone interviews with mothers of the first-grade girls were used to collect the data on the home environment, including family socioeconomics, maternal spatial skills, general quality of the home learning environment, and girls' math and spatial activities. Prior to the telephone interviews, families were mailed questionnaire packets. Mothers were asked to follow along in their packets during the interview, primarily because the spatial skills assessment required them to view stimuli. Interviews lasted, on average, approximately 45 min.

The interview protocol was adapted from telephone interview procedures used with families of first graders in the NICHD Study of Early Child Care and Youth Development (Early Child Care Research Network, 2011). Interviewers included the study principal investigator and graduate students, each of whom completed several training/pilot interviews under the supervision of the study lead investigators. For the small number of Spanish-speaking mothers, the interviews were conducted in Spanish by a native Spanish speaker, after translating questionnaires and the interview protocol, and after these translations were reviewed and back-translated by a second native Spanish-speaking graduate student.

To assess girls' arithmetic, verbal, and spatial skills, we conducted three days/sessions of in-school individual assessments. For each testing session, girls were taken out of the regular classroom and tested in a quiet classroom location. During the first session, girls completed the 3-d and 2-d mental rotation tasks. During the second session, girls were administered the WISC-IV Block Design subtest and the Peabody Picture Vocabulary Test (PPVT). During the third testing session, girls completed addition and subtraction problems.

5.3. Interview questionnaires

5.3.1. Family demographics and socioeconomics

Mothers reported on a variety of household demographic characteristics, including race/ethnicity as well as their number of years of education and family annual income. Mothers also indicated their total family size and the number of children who lived in the home. A ratio of family income-to-needs was calculated by dividing family income by the appropriate poverty threshold, based on family size and number of children. Mothers were also asked three Likert-type questions about family economic strain that were developed by the Early Child Care Research Network (2011): "Overall, how satisfied are you with your financial situation?", "How often do you worry about financial matters?", and "Some people worry about whether they have enough money to live on from one month to the next. How often do you worry about this?" After we reverse scored the first item, we averaged responses; this measure was negatively correlated with family income-to-needs ($r = -.64$).

5.3.2. General home learning environment

To measure the general quality of the home learning environment, mothers reported on 13 dichotomous (yes/no) items taken from the middle childhood version of the Home Observation for Measurement of the Environment (HOME; Caldwell & Bradley, 1984). The HOME was designed to capture aspects of children's homes that are salient for their cognitive, language, and social–emotional development, and it has been validated in economically-diverse samples (Caldwell & Bradley, 1984). The full version of the HOME has 8 subscales, comprised of 59 items that are accessed using parent interview or observation. Given our use of telephone interviews and our interest in the learning environment, we used all of the items from three of the subscales that were designed to be accessed via interview (rather than observation): enrichment (7 items, e.g., "Has a family member taken her to an art, science, or history museum within the past year?" and "Does her family encourage her to develop hobbies?"; $\alpha = .64$), learning materials (6 items, e.g., "Are there musical instruments in the home that she can use?" and "Does she have a desk or special place for reading or studying?"; $\alpha = .51$), and family companionship (4 items, e.g., "Does an adult family member talk with her about TV programs

Table 1
Math activity questionnaire items.

Child math activities	Cronbach's α if item deleted
Uses a calculator	.81
Uses computer or video games to do addition, subtraction or other math activities	.81
Shows interest in or talks about time using clocks	.80
Plays card games that use numbers or counting (such as Go Fish, War)	.80
Counts down using numbers (10, 9, 8, 7, . . .)	.80
Plays board games that use numbers, counting, or dice (such as Chutes and Ladders, Monopoly Jr.)	.80
Counts out money	.80
Memorizes math facts (such as 2 + 2)	.80
Wears and uses a watch	.81
Measures the lengths and widths of things	.80
Solves problems with numbers bigger than 10	.81
Guesses the number of things (such as pennies in a jar)	.80
Adds or subtracts numbers in her head	.81
Times how fast an activity can be completed (using a clock or stopwatch)	.81
Uses a calendar and talks about dates	.82
Compares the sizes of numbers (such as 5 is more than 4)	.80

Table 2
Spatial activity questionnaire items.

Child spatial activities	Cronbach's α if item deleted
Plays with toy soldiers, action figures, cars/trucks, planes, or trains	.84
Folds or cuts paper to make 3-d objects (such as origami, paper airplanes)	.84
Does arts and crafts projects (such as making jewelry, stringing beads, or using play dough/clay)	.84
Colors, paints, or draws free hand (not filling-in outlines)	.84
Uses computer or video games to do drawing or painting or matching and playing with shapes	.85
Uses tools (such as hammer or screwdriver) to make things or takes things apart to see how they work (such as a broken flashlight or toy)	.84
Sets up play environments with toy furniture, toy buildings, train tracks or building blocks	.84
Explores woods, streams, ponds, or beaches or searches for plants, bugs, or animals outdoors when the weather permits	.84
Races toy animals or cars on the ground or around obstacles	.84
Builds with construction toys (such as building blocks, Legos, magnet sets, Lincoln logs)	.83
Plays with puzzles (such as picture puzzles, tangrams, slide puzzles, 3-d puzzles)	.84
Plays paper and pencil games (such as mazes, connect-the-dots)	.84
Sets up obstacle courses, tunnels, or runways for kids or pets	.84
Draws maps (such as treasure hunt maps)	.83
Draws plans for houses, forts, castles or other buildings or layouts	.85
Plays in parks or green spaces when the weather permits	.84
Uses kits to build models (such as airplanes, animals, dinosaurs, doll houses)	.84
Climbs trees when the weather permits	.85
Plays with flying toys (such as kites, paper airplanes)	.84
Builds dams, forts, tree houses, snow tunnels or other structures outdoors when the weather permits	.84

she watches?" and "Does a family member help her to learn how to ride a two-wheel bicycle, roller skate, ice skate, or play ball?"; $\alpha = .66$). Average maternal responses on these three subscales were significantly correlated ($p < .05$) at .36 (learning materials and family companionship), .51 (enrichment and family companionship), and .54 (enrichment and learning materials). Internal reliabilities for these subscales improved considerably by dropping items that were weakly correlated with the rest (e.g., dropping two items from the learning materials subscale raised the alpha level to .77), but we followed the scale author's advice to retain all items; dropping items from HOME subscales to improve reliability comes at the more serious cost of failing to be thorough in capturing a range of child experiences in the home environment (Bradley & Corwyn, 2004).

5.3.3. *Child math and spatial activities*

Mothers rated their daughters on a scale of 0 (never) to 4 (many times per week) to indicate how often their daughter engaged in 36 activities: 16 math- related and 20 spatial-related items (see Tables 1 and 2). Mothers were asked to include activities that their daughter might have done: by themselves, or with brothers, sisters, mother, father, other females in the home, other males in the home, or male and female playmates. The majority of our math items were adapted from the works of LeFevre et al. (2009). The majority of our spatial items were adapted from the works of Newcombe, Bandura, and Taylor (1983), Robert and Heroux (2004), and Serbin and Connor (1979). In addition, some items were developed for the present study based on focus groups with elementary school-age girls, women, and parents. Examples of the math activities included: "uses computer or video games to do addition, subtraction or other math activities" and "plays card games that use numbers or counting (such as Go Fish, War)". Examples of the spatial activities included: "folds or cuts paper to make 3-d objects (such as origami, paper airplanes)," and "builds with construction toys (such as building blocks, Legos, magnet sets, Lincoln logs)." Both scales proved to be reliable ($\alpha = .82$ for math and $\alpha = .85$ for spatial), with the complete item lists (and reliability changes if items deleted) provided in Tables 1 and 2.

5.3.4. *Response bias*

As a control for response bias (i.e., a social bias toward reporting high frequencies of activities) and/or general child activity level (i.e., girls who were very active or inactive overall, regardless of activity domain), mothers reported on their girls frequency of involvement in two additional activities: "plays with dolls, stuffed or plastic animals, or toy people" and "watches TV (such as children's shows, nature shows, cartoons)." By averaging these two items, we formed a composite (i.e., higher scores indicated higher activity frequency across the two items). The potential usefulness of this variable as a covariate in our analysis was underscored by the fact that mothers' reports of high frequencies on this composite were positively correlated with reports of high frequencies for arithmetic ($r = .32$) and spatial ($r = .14$) activities, albeit at a non-significant level ($p = .10$) for the latter.

5.3.5. *Maternal spatial skills*

A brief mental rotation test, adapted from the *Vandenberg Mental Rotation Test* (Vandenberg & Kuse, 1978), was given to the mothers. It consisted of five mental rotation items from the Vandenberg. Each item had a picture of a 3-d object on the left called the target object. On the right, there were pictures of four 3-d objects; two of the four pictures were identical to the target object, but rotated to a different orientation. The two incorrect, distractor items, were mirror-images of the target objects, also rotated to different orientations in space. The task is to select the two objects that are identical to, albeit rotated versions of, the target object. For each item, the 2-d drawings of the 3-d objects were represented as being constructed out of cubes. Scores could range from 0 to 10: on each of the five items, mothers were given two points for selecting both of the correct objects, one point if they selected one correct and one incorrect object, and zero points if both choices were incorrect.

5.4. Child verbal, arithmetic, and spatial skills measures

5.4.1. Verbal skills

The *Peabody Picture Vocabulary Test-Fourth Edition* (PPVT-IV; Dunn & Dunn, 2007) was used to assess girls' verbal skills. This is a norm-referenced measure of receptive vocabulary, and is administered by presenting a stimulus word (spoken by tester) and asking children to identify a pictorial representation of that word from four choices. This measure has demonstrated excellent reliability and validity in socioeconomically diverse samples (Dunn & Dunn, 2007), and inter-item reliability was high ($\alpha = .90$) in the present sample.

5.4.2. Arithmetic performance

Girls solved 10 addition problems and then 10 subtraction problems, with problem order counterbalanced across individuals. Problems included either two 1-digit numbers, or one 2-digit number and one 1-digit number (adapted from Carr & Jessup, 1997). The problems used integers between 2–9 and 12–19, with the constraint that the same two integers (e.g., 3 + 3 or 6 − 6) were never used in the same problem. The range of sums was 9–24; the range of differences was 3–15.

Before beginning, the researcher placed color tiles on the table and told the child she could solve the problem in any way she chose (i.e., "You can count on your fingers, count on the counters, do the math in your head, or you might just know the answer."); each of these different approaches was, in fact, used by multiple girls. Then, each problem was presented, written horizontally on a card (e.g., 7 + 3) and read aloud (e.g., "What is seven plus three?"). One point was given for each item solved correctly. Both 10-item scales demonstrated excellent inter-item reliability ($\alpha = .84$ for addition; $\alpha = .85$ for subtraction).

5.5. Spatial performance

To investigate spatial skills, three measures were used, which incorporated age-appropriate spatial tasks assessing spatial visualization and mental rotation skills, two key aspects of spatial reasoning (Linn & Petersen, 1985; Voyer, Voyer, & Bryden, 1995). More specifically, these three spatial measures included the ability to mentally visualize, manipulate, and rotate objects in space, and to combine parts to make wholes. The measures of spatial skills were chosen because they were specifically designed to assess spatial skills in young children, have been found to relate to other spatial measures and activities within this age group, and assess the kinds of spatial skills that have been shown to predict for general math performance in older students (Cannon et al., 2007; Casey et al., 2008; Halpern et al., 2007; Levine et al., 1999; Novak, Tshushima, & Tshushima, 1991; Serbin & Connor, 1979).

The *Block Design* subtest of the *Wechsler Intelligence Scale for Children-Fourth Edition* (WISC-IV) (Wechsler, 2003) was selected as a measure because it is one of the most frequently used instruments for assessing children's spatial skills (Caldera et al., 1999; Serbin & Connor, 1977, 1979). This subtest is considered to be the core of the Perceptual Reasoning Index of the *WISC-IV*, and is designed to measure the ability of 6- to 12-year-olds to analyze and synthesize abstract visual stimuli—in particular—the ability to separate figure and ground in visual stimuli (part–whole relations). In the Block Design subtest, the child is shown a series of 14 pictures of red and white 2-dimensional patterns. The child is asked to match each picture pattern by arranging a set of small cubes (some sides all red, some all white, and some half red and half white on the diagonal) so that the assembled top surfaces of the blocks matches the picture. Test-retest reliability and validity have been repeatedly established in socioeconomically diverse samples (Novak et al., 1991; Wechsler, 2003). The pre-kindergarten Block Design score was one of the best predictors of later school achievement in grades one and two (Novak et al., 1991).

We also assessed girls' spatial skills using a subset of 16 items from the 32-item *Mental Transformation Task* (Levine et al., 1999). These items, developed for 4- to 6-year-olds, require children to match a target–a picture of two halves of a shape rotated in 2-d space – to four choices of possible completed figures, in which only one of the four figures was actually formed by the two rotated halves. All of the items required mental rotation of the shape halves in order to match the whole figure. Specifically, children had to identify the correct whole shape from among four choices in a 2 × 2 array that could be formed from the halves. There were two types of mental rotation problems (8 items of each type), which varied with respect to the relative positioning of the two target pieces. In the first type, the horizontal placement, each target piece was rotated 60° from the vertical axis, one clockwise and the other counterclockwise. In the second type, diagonal placement, the target pieces were again rotated 60 degrees from the vertical, but, in addition, the closest points of the pieces were separated by about 2 cm along *both* the horizontal and vertical axes, which placed the pieces diagonally from one another on the page (see Levine et al., 1999 for details on procedures and stimuli used for this task). The inter-item reliability of the items was $\alpha = .71$ in the present study.

The third spatial task consisted of a 14-item 3-d mental rotation task that was adapted from a similar 10-item task developed for kindergarten-age children (Casey et al., 2008). The task consisted of 14 identical pairs of 3-d figures. Each 3-d figure was made out of multi-link cubes that were taped over with blue tape so that each figure had a gestalt of a solid 3-d object. Children had to both flip (3-d rotation) and turn (2-d rotation) one of the identical figures so that it was placed in the same orientation as the other identical figure. Thus, they had to physically rotate objects in 3-d space. The tasks increased in difficulty level across the 14 items by increasing the complexity of the figures in two ways – by adding more multi-link cubes to the core block structure and by increasing the number of directions that the cubes extended from this core. Participants were given 10 s to solve each problem. Within 10 s, the item was scored as correct if the first figure was in the same orientation as the second figure, or incorrect if the first figure was not in the same orientation as the second figure. (See Casey et al., 2008 for detail on procedures and stimuli for this task.) This mental rotation measure appeared valid (e.g., $r = .45$ with WISC-IV Block Design). Inter-item reliability ($\alpha = .54$), however, was low. Because of this low reliability, we estimated all of our analyses with and without this measure. Dropping the 3-d rotation measure had no statistically distinguishable impact on our measurement model. Moreover, there was no change in the pattern of statistically significant results in our structural models with and without the 3-d measure, except to slightly – not significantly – reduce effect sizes for predictors of our spatial skills latent construct.

5.6. Statistical analyses

We estimated structural equation models (SEM) to examine direct and indirect associations between girls' home learning environments and their arithmetic and spatial performance; best practice recommendations were followed for evaluating measurement, path, and structural models (e.g., Anderson & Gerbing, 1988; MacCallum & Austin, 2000; McDonald & Ho, 2002). Specifically, we first examined a measurement model (i.e., confirmatory factor model) in which our measured variables were estimated as indicators of the proposed latent variables depicted in Fig. 1. Although not included in the figure for reasons of brevity, our measurement model also included ethnicity and response bias.

As a follow-up to the measurement model, we estimated the hypothesized structural model (Fig. 1). The measurement model

Table 3
Descriptive statistics for observed variables.

Variable	*M* (SD)
Math skills	
Addition	.84 (.23)
Subtraction	.72 (.29)
Spatial skills	
2-d mental rotation	.64 (.20)
3-d mental rotation	.62 (.17)
WISC Block Design	10.17 (3.05)
Math activities	2.04 (.57)
Spatial activities	1.72 (.49)
Verbal skills (PPVT)	107.86 (15.46)
Home environment	
Enrichment	.76 (.17)
Family companionship	.88 (.15)
Learning materials	.77 (.15)
Maternal mental rotation skills	1.18 (.45)
Maternal education (years)	15.96 (3.18)
Family income-to-needs	4.27 (4.08)
Family economic strain	2.77 (.99)

served as the null structural model (i.e., no path constraints) and we considered both the overall goodness of fit for the structural model as well as the underlying goodness of fit for the path model. Ethnicity and response bias served as covariates such that (a) response bias was always included as a control variable in path equations predicting the math and spatial activity constructs, and (2) ethnicity was always included as a control in path equations predicting the math and spatial outcome constructs. Although not presented in Fig. 1 for simplicity, our structural models also included a covariance path between math and spatial activities, with the expectation that these constructs would be positively correlated. In addition, although SEM is not a panacea for all sources of measurement error, it is worth noting that one of its strengths is the statistical adjustment for unreliability caused by inter-rater and/or inter-item measurement errors (DeShon, 1998); estimated associations among latent constructs are disattenuated to correct for measure unreliability.

5.6.1. Missing data

Across all observed variables, 82.5% of the data were complete. No participants were missing child arithmetic, spatial, or verbal intelligence testing data; however, 28.3% of families did not fully complete telephone interviews. To adjust for potential bias caused by missing data, we used full information maximum likelihood estimation. Best practice recommendations for SEM with moderate amounts of missing data (e.g., Enders & Bandalos, 2001; Widaman, 2006) are that full information maximum likelihood (i.e., FIML) estimation be used, if variables related to missingness can be included in the analysis; in the present study, all of the child arithmetic, spatial, and verbal performance results were negatively correlated with missingness such that girls missing home interviews demonstrated lower performance (*r* ranging from −.15 to −.37). Moreover, the primary pattern of results was robust to re-specification using listwise deletion and other imputation methods (e.g., single imputation with an EM-algorithm). Table 3 provides descriptive statistics for study variables based on starting values in our structural equation models.

6. Results

6.1. The measurement model

The first step in our analytic plan was to estimate a measurement model for the latent constructs depicted in Fig. 1. For four of the nine hypothesized latent constructs, multiple indicators were observed: two for family economics (family income-to-needs and economic strain), three for home learning investments (enrichment, learning materials, and family companionship), two for arithmetic performance (addition and subtraction), and three for spatial performance (Block Design, 3-d mental rotation, and 2-d mental rotation). For the five constructs with a single observed indicator (maternal education and spatial skills, child verbal intelligence, math activities, and spatial activities), we took a relatively conservative approach to estimating measurement error variance, assuming for each measure that the corresponding error was equal to 15% of that measure's overall variance (Jöreskog & Sörbom, 1993). The resulting factor loadings and global fit indices for the measurement model, as displayed in Fig. 2, indicated good fit to the data (e.g., null χ^2 and RMSEA value less than .05).

6.2. The structural model

The second step in our analytic plan was to estimate a series of structural models examining direct and indirect pathways of association between the girls' home learning environments and their arithmetic and spatial performance. We started with the hypothesized model (Fig. 1) and then estimated alternative models that provided either empirically-guided or conceptually-guided comparisons with the hypothesized model. All structural models for which we constrained one or more pathways of association were compared with the null model (i.e., the measurement model depicted in Fig. 2, in which all latent constructs were allowed to correlate), partitioning the goodness of fit associated with the (a) underlying path and (b) underlying measurement components of the models as recommended by McDonald and Ho (2002).

Acceptable model fit was indicated for the overall structural model (i.e., $\chi^2 = 132.38$, df = 118, $p = .17$ and RMSEA = .03) and the underlying path model (i.e., structural-model χ^2 – null-model $\chi^2 = 42.44$, df = 35, $p = .18$, RMSEA = .04). Modification indices, however, indicated additional paths to improve model fit. First, a direct path from home learning investments to arithmetic performance was specified; by adding this path, direct and indirect (via activities) associations between home learning investments and arithmetic performance were estimated. Second, a path from child verbal skills to home learning investments was estimated; given that a direct path from the home to verbal skills was already specified, the second predictive path captured reciprocal effects of child verbal abilities on the home learning context. Pathways of association were also added that controlled for ethnic differences in family economics, maternal education, home learning investments, and math activities. In addition, we dropped the covariance path for arithmetic and spatial performance, because these constructs proved to be unrelated ($p = .50$).

These modifications resulted in a statistically significant improvement in global model fit (Δ in global fit, $\chi^2 = 15.60$, df = 3, $p < .01$; structural model, $\chi^2 = 116.78$, df = 115, $p = .44$, RMSEA = .01; path model, $\chi^2 = 26.84$, df = 32, $p = .73$). In total, the estimated path model accounted for approximately half of the variance in girls' arithmetic and spatial performance (45% and 47%, respectively). In Fig. 3, we have displayed path coefficients for this model; all statistically significant associations presented in this figure were significant prior to model modifications as well. Also displayed in the figure are partial correlations that are correctly interpreted as effect sizes. In addition, in Table 4, we have listed the statistically significant indirect effects, computed using the product of coefficients.

6.2.1. Primary results: direct and indirect associations

Four important findings were evident in the best fitting structural model. First, girls' home learning environments and, in turn,

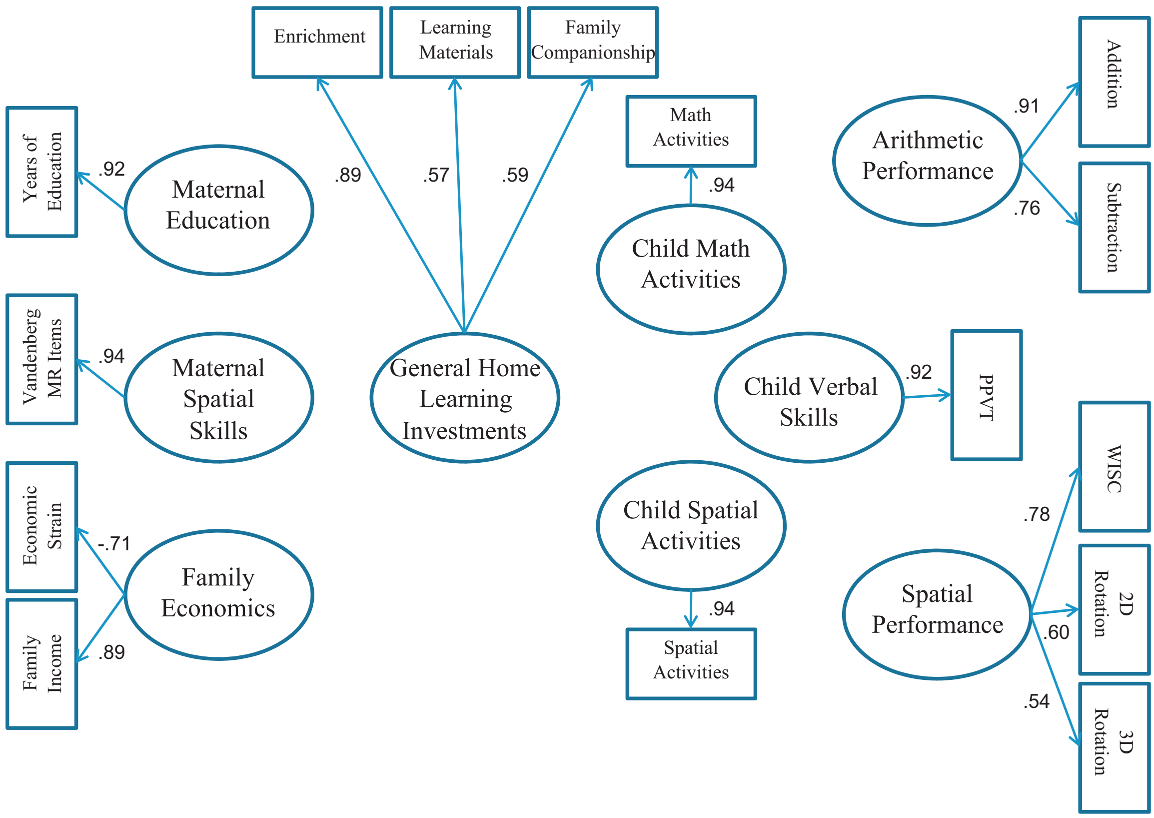

Fig. 2. Measurement model loadings and model fit (χ^2 (83) = 89.94, p = .28; RMSEA = .03, 90% CI = .00–.06).

their engagement in math-related activities were proximal predictors of arithmetic performance (r = .19 and .29, respectively). These proximal predictors mediated the more distal effects of family socioeconomics (in Table 4, see indirect effects 1–3). Girls whose mothers had high levels of education and whose families had high levels of economic resources received the highest levels of investments into their general home learning environments. In turn, these investments in the general home learning environment were both directly and indirectly associated with high arithmetic performance; regarding the indirect association, high

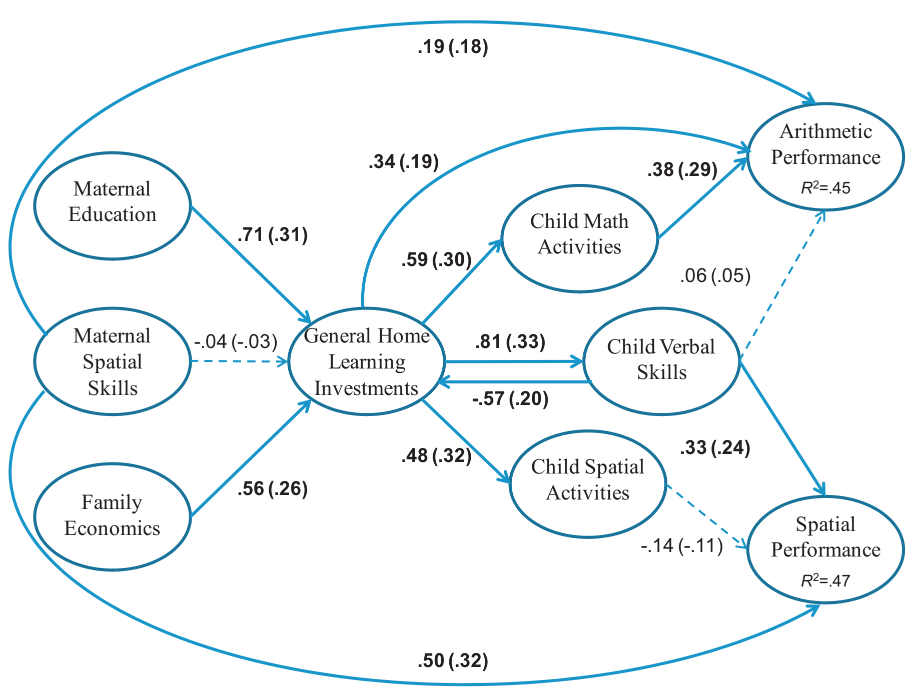

Fig. 3. Structural model of direct and indirect associations linking home learning environments with girls' arithmetic and spatial performance (χ^2 (115) = 116.78, p = .44; RMSEA = .01, 90% CI = .00-.05). Solid lines indicate statistically significant associations (p < .05); dashed lines indicate null associations.

Table 4
Indirect effects from distal aspects of home learning environments to girls' arithmetic and spatial performance.

Path of association	Indirect effect (*ab*)
1. Maternal education → home learning investments → math-related activities	.09*
2. Family economics → home learning investments → math-related activities	.08*
3. Home learning investments → math-related activities → math performance	.09*
4. Maternal education → home learning investments → spatial activities	.10*
5. Family economics → home learning investments → spatial activities	.08*
6. Maternal education → home learning investments → verbal skills	.10*
7. Family economics → home learning investments → verbal skills	.09*
8. Home learning investments → verbal skills → spatial performance	.08*

* $p < .05$.

learning investments predicted girls' engagement in math-related activities, which was the strongest proximal predictor of high arithmetic performance.

Our second important finding was an unexpected null result: spatial performance did not appear to be environmentally mediated by spatial activities, despite the fact that socioeconomic advantage and home learning investments appeared to promote girls' engagement in these activities. Home learning investments were a proximal predictor of girls' engagement in spatial activities, mediating more distal associations between socioeconomic advantage and engagement in these activities (in Table 4, see indirect effects 4–5). Yet, the association between spatial activities and spatial performance was nonsignificant and negative ($r = -.11$, $p = .22$). Thus, spatial activities did not appear to benefit girls' spatial performance.

The third result worth noting, however, was that girls' verbal skills were a proximal predictor of their spatial performance, mediating the indirect effects of home learning investments and, more distally, family socioeconomics on spatial performance (in Table 4, see indirect effects 6–8). Girls in more socioeconomically advantaged families displayed better verbal skills than other girls, and this was explained primarily by the high levels of learning investments occurring in socioeconomically advantaged homes. In turn, verbal skills directly predicted girls' spatial performance. Taken together, these results suggest that girls' spatial performance is environmentally mediated, at least in part, through the influence of home learning investments on their verbal skills. On the other hand, our expectation that verbal skills would also be a proximal predictor of girls' arithmetic was not supported. Yet, as a side note, it was interesting that verbal skills were associated with the general home learning environment in a reciprocal fashion. Adjusting for the fact that higher levels of learning investments predicted better verbal skills for girls, the remaining variance in these two constructs was negatively correlated such that worse verbal skills, in turn, predicted higher levels of investments in the general home learning environment.

A fourth important finding evident in the path model was that maternal spatial ability was directly associated with girls' arithmetic and spatial performance ($r = .18$ and $.32$, respectively). Surprisingly, however, we found no evidence consistent with our expectation that maternal spatial ability would be, at least in part, indirectly associated with girls' performance via the home learning environment. Maternal spatial skills were, in fact, not associated with family investments into the home learning environment.

7. Discussion

The present study was designed to move beyond the extensive research on gender differences relating to math and spatial skills by focusing exclusively on factors that contribute to young girls' arithmetic and spatial skills. In so doing, we gave special attention to their early home learning environments. One important contribution of the present study was our finding that math activities were closely related to girls' arithmetic skills, largely accounting for the more distal effects of family socioeconomics and, in part, the overall level of learning stimulation in the home. Higher levels of maternal education and family economic resources predicted more home investments in learning stimulation, which predicted young girls' engagement in more math activities and, ultimately, better math skills. Surprisingly, however, spatial activities were not related to spatial skills. Although family socioeconomics predicted engagement in spatial activities via home learning investments, these activities were *not* associated with girls' spatial reasoning skills. Instead, verbal skills and their mothers' spatial skills were the only predictors directly linked with girls' spatial skills.

7.1. Predictors of early arithmetic skills

Previous laboratory and descriptive studies of the home environment (Blevins-Knabe & Musun-Miller, 1996; LeFevre et al., 2009; Ramani & Siegler, 2008) are consistent with our results that engagement in math activities positively predicts first-grade girls' arithmetic performance. The new finding in the present study is that these types of math activities are the most proximal predictors of arithmetic achievement, and in combination with the quality of the home environment, mediate SES differences in girls' arithmetic performance. In fact, once accounting for the general quality of girls' home learning environments and their math activities, there was no direct association between family socioeconomics and arithmetic skills.

This indirect link between SES and arithmetic performance was consistent with the hypothesized sequence, whereby socioeconomic resources allow parents to make material and psychosocial investments in the home and, in turn, learning stimulation increases the likelihood that children will engage – independently and jointly with parents – in a variety of learning activities that emphasize numerical reasoning. Although there is a rich body of research on how parents can further their children's early reading skills, there is a dearth of information on specific ways in which parents can facilitate their children's math skills. Given this limited knowledge, the present findings may provide intervention targets for promoting girls' long-term achievement.

Even when financial resources are limited for families, parents may be able to provide many of these early math experiences (e.g., measuring and comparing quantities, memorizing math facts, and discussing time using a clock). Indeed, there is ethnographic evidence that families in poverty often find clever and valuable solutions for investing in children's educational success despite material deprivation. Weiss and colleagues (Weiss et al., 2005; Weiss et al., 2003), for example, have documented the ways that low-income parents compensate for limited books in the home, taking advantage of materials such as a Bible or tabloid newspaper for shared reading. These same authors, however, also point that low-income parents appear to give less attention to math activities. Alongside our findings, this evidence seems to indicate considerable potential for intervention with math activities in low-income homes.

The association between general quality of the home learning environment and arithmetic skills was not entirely mediated by math activities, however. There were still proximal effects of the general home environment on arithmetic achievement. We suspect that this remaining direct connection between the general quality of the home learning environment and girls' arithmetic skills is due to the positive effects that learning stimulation has on factors such as attitudes, motivation, and metacognitive reasoning (Dearing & Tang, 2010; Grolnick et al., 1999). In other words, within enriched home learning contexts, girls engaged in math activities that predicted better arithmetic skills and likely gained more general learning and metacognitive skills.

It is interesting to note that maternal spatial skills were directly associated with girls' arithmetic and spatial skills, rather than mediated by the home environment or child activities. We believe there are two possible explanations for this finding. First, it is possible that our measures of the home environment did not fully capture mathematical experiences provided by spatially gifted mothers. In other words, mothers with high spatial ability may interact with their daughters differently and/or provide unique environmental stimulation not assessed through either the general home environment or activities measures used in the present study. Although our home environment and activity measures were purposefully thorough in capturing a range of environmental factors, they may fail to capture more nuanced aspects of spatially-gifted mothers' behaviors that are important for promoting their daughters math abilities. Second, however, genetic mechanisms must be considered. Although an empirical disentangling of these alternative explanations is beyond the scope of our study, the result for maternal spatial skills underscores the value of including this measure and, more generally, the value of bio-ecological approaches to understanding early environments.

7.2. Predictors of early spatial skills

The fact that spatial activities did not positively predict spatial skills in these young girls was unexpected, especially because these activities were, in all other respects, associated with girls' environments and activities; girls who lived in enriched homes and who engaged in relatively high levels of math activities also engaged in the most spatial activities. Further, in other research, spatial experiences have been shown to have a small but significant relation with spatial skills in females (Baenninger & Newcombe, 1989; Voyer, Nolan, & Voyer, 2000). Given this null result, it is worth considering that the relatively low reliability of our 3-D spatial measure may have biased associations toward zero for this construct.

Yet, girls' verbal skills did appear to benefit the spatial performance of these young learners. In fact, the indirect path from home learning environment to verbal skills and, in turn, to spatial performance was sufficient to account for SES differences in this domain. This link between young girls' verbal skills and their spatial performance is not surprising, as it fits with prior research indicating that many females prefer to use verbal, analytic strategies when solving spatial problems rather than applying the holistic mental spatial manipulation strategy that is more consistently found with males (Janssen & Geiser, 2010; Jordan et al., 2002; Pezaris & Casey, 1991). Thus, it may be the quality and depth of the spatial language environment experienced by girls, rather than exposure to specific spatial activities, that is more critical for girls' early acquisition of spatial skills. It has recently been shown, in fact, that for girls, but not for boys, the amount of spatial language used by mothers when interacting with their toddlers while playing with puzzles is related to their daughters' later spatial skill in preschool (Cannon et al., 2007).

It is interesting, therefore, that in addition to girls' verbal ability, mothers' spatial skills also predicted their daughters' spatial skills. Mothers' spatial ability was the strongest predictor of their daughters' spatial performance. This relationship may be due, at least in part, to genetic inheritance. Yet, spatially talented mothers may also provide spatially rich environments that were not captured in the present study; mothers with high spatial abilities may interact with their daughters differently, and may create distinct environmental experiences, which, in turn, facilitate their daughters' spatial skills. Further examinations of the spatial learning environments that parents create for their girls are needed to disentangle these alternatives.

7.3. Limitations of the present study

Our study adds to the cumulative knowledge on home learning environments, because arithmetic and spatial stimulation in this context have received too little attention. Yet, limitations to the present study are worth noting. First, for some of our measures, low inter-item reliability was a concern. Associations may have, for example, been biased toward zero for general home learning investments and spatial skills, two latent constructs that contained at least one indicator with low reliability.

Response bias was also a concern in the present study. Despite our attempt to control for it, social desirability may have led mothers to mischaracterize their households. Such bias in maternal responses would impact our results to the extent that it was non-randomly distributed across study factors. On a related note, another potential limit of the study is that we may have missed important activities or general learning investments, inside or outside the home. In particular, it is worth considering that girls in our sample were at the bottom of the age range (6–10 years) for the HOME measure we used; some parents may have viewed certain activities as not yet developmentally-appropriate, but still engaged in similar activities (e.g., taking their girls to parent–child art activities at a community center rather than going to an art museum). And, without fathers' reports we may have missed activities not observed by mothers.

Moreover, our analyses were focused exclusively on one aspect of girls' bio-ecological systems, namely their homes. Girls' experiences and activities outside of the home may also be directly or indirectly related to both arithmetic and spatial performance, or may moderate evident associations. High-quality early child care has, for example, proven to moderate the association between poverty and math performance across the elementary school years (e.g., Dearing et al., 2009). Nonetheless, with so little existing work in this area, our phone interviews provided efficient means to capture a relatively broad range of math and spatial activities for young girls.

It is also important to note that without longitudinal data, we were not able to study growth. In addition, our use of contemporaneous measurements leaves open the potential for simultaneity bias (i.e., reciprocal causation); for example, rather than math activities positively influencing arithmetic performance, this association may be due, at least in part, to girls with high arithmetic abilities being more likely than other girls to independently choose such activities or evoke from their parents a family emphasis on such activities. On a related note, our inferences based on the structural models are limited to considerations of whether or not our results are *consistent* with causal hypotheses. There remains the potential for omitted variable bias; characteristics of girls or their environments that were not observed in the present study could be the true cause of high arithmetic and spatial performance. As a descriptive study, however, we believe this work should help target strategies for designing randomized intervention studies, in particular identifying math activities in the home environment that would be worth targeting.

In addition to these limitations, it is worth considering that our focus on girls does not allow us to speak to whether the evident patterns of association are unique to girls, or whether they may, in fact, generalize equally well to boys. In designing the present study, we maximized statistical power for detecting individual differences among girls by sampling only this gender. Given the understudied nature of within-gender questions, our study is a useful step in advancing the knowledge base. Yet, large sample studies that have the power to simultaneously estimate associations across and within genders will provide a valuable extension in this line of work.

8. Conclusions

Moving beyond gender differences and similarities to a within-gender study of young girls, we found that early home learning environments plus math activities largely explain socioeconomic differences in first-grade girls' arithmetic performance. These findings suggest that there are specific kinds of home and math experiences that young girls can be exposed to *independent of* their family's socioeconomic situation. This has positive implications for family interventions. For girls from low-SES families, such efforts could prove especially valuable, because these girls demonstrate the largest underachievement in mathematics.

Further, the present study makes an important contribution by showing the sharply differing patterns of predictive relations for arithmetic skills versus spatial skills. For spatial tasks, verbal ability was an important predictor of girls' skills, helping account for the effects of socioeconomics and, in turn, home learning investments. Our findings seem to indicate that general investments in the home environment that promote verbal skills should also prove useful for girls' spatial skills. However, an alternative possibility is that young girls with high spatial ability depend on verbal analytic approaches because they have not yet learned how to effectively apply spatial strategies (Kaufman, 2007).

Finally, given the importance of mothers' spatial abilities both on their daughters' arithmetic and on their spatial abilities, further investigation is needed into the ways in which spatially gifted mothers affect the spatial and math learning environments of their daughters. One approach is to directly observe mothers' interaction patterns with their daughters as they jointly solve spatial and math problems. This may help to capture the more subtle ways in which these mothers differentially impact their daughters' home learning environments.

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