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**Home Sweet Home? Examining Residential Instability and Preschoolers' Early Mathematics
Development**

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Abstract

In 2020, approximately 13% of all children under five experienced residential instability. Residential instability, also known as housing instability, is known to compromise the socio-emotional and behavioral development of young children. However, there is limited evidence documenting the effect of housing instability on preschoolers' cognitive and academic abilities, in particular the development of mathematics skills. The present literature review argues that unstable residential conditions have important implications for preschoolers' early mathematics development. First, the current literature review explores the implications of residential instability for the early childhood developmental period. Then this review examines current studies on promotive and risk factors for early mathematics development of preschool children. Next this review synthesizes current evidence on the impact of housing instability on school readiness of preschool children. The present literature review closes by discussing future directions for research and practice in math acquisition of preschool children experiencing poor housing conditions.

Keywords: residential instability, early childhood, school readiness, early mathematics development

Home Sweet Home? Examining Residential Instability and Preschoolers' Early Mathematics Development

Albeit without standard definition, residential instability is recognized as paying a substantial proportion of income on housing, overcrowding, staying with relatives, frequent moves, and difficulty paying rent (Kushel et al., 2006; Frederick et al., 2014). Current literature on housing insecurity categorizes residential instability as being reactive or voluntary (Kang, 2019; DeLuca et al., 2019). Literature on inadequate housing also suggests that residential mobility among low-income populations is a result of housing, family, and neighborhood crises (Clark & Onaka, 1983).

In 2020, approximately 13% of all children under five years of age experienced residential instability (U.S. Census Bureau, 2020). Residential instability often referred to as housing instability, has been found to be negatively associated with developmental, health and educational outcomes for children.

A growing body of literature shows that residential instability adversely impacts developmental outcomes for children through disrupted routines, loss of social support networks, disrupted school experiences, increased parenting stress, and diminished quality of parenting (Sandstrom & Huerta, 2013).

Housing instability during the early years of life has also been shown to have a lasting impact on children's mental health (Sandstrom & Huerta, 2013). Rumbold et al. (2012) showed that insecure housing during the first two years of life leads to increased internalizing behavior such as anxiety, sadness, and withdrawal at age nine. Other studies affirm to these findings suggesting that experiencing unstable housing conditions in childhood negatively effects children's psycho-social health (Baker et al., 2019). Furthermore, these suboptimal psycho-social health outcomes are more pronounced for children who already have poor health outcomes (Baker et al., 2019). Baker et al. (2019) also found that children who experience more than three residential moves before the age of four have a higher body

mass index (BMI) than children who experience no residential moves. These findings suggest that residential instability reinforces health inequalities among children.

Beyond mental and physical health outcomes, poor housing conditions have negative bearings on the cognitive achievements and schooling outcomes of young children (Leventhal & Newman, 2010). For young children experiencing residential instability, the development of school readiness skills often stops, with children performing relatively worse on kindergarten readiness scores than their counterparts (Coulton et al., 2016). Studies looking at housing instability from a developmental perspective have demonstrated that frequent residential moves are associated with decreased inhibitory control, math, and literacy learning outcomes for young children (Schmitt et al., 2015). Residential instability is also found to have detrimental effects on home learning environments of preschool children, which ultimately minimizes their readiness for school (May et al., 2018). Furthermore, unstable housing also impacts later schooling outcomes for children in the form of weaker vocabulary skills, higher grade retention, higher high school drop-out rates, and lower adult educational attainment than their residentially stable peers (Sandstrom & Huerta, 2013).

Given the high rates of housing instability among U.S. children and evidence that links inadequate housing with compromised outcomes in socioemotional, cognitive, and behavioral development, mental and physical health, as well as school readiness and later schooling, it is critical to understand the implications of residential instability during the early childhood period (Molborn et al., 2018).

Young children tend to learn best when they have secure and stable relationships and feel physically safe. Thus, access to high-quality early childhood programs can be beneficial for young children as it provides them with safe and secure environments and therefore the foundation needed to support school readiness skills. One crucial school readiness skill is early mathematics. According to The National Association for the Education of Young Children (NAEYC), mathematics is a part of a young child's everyday life and predicts later academic achievement better than early reading (Master, n.d.).

According to the Head Start Early Learning Framework, early mathematics knowledge includes a child's ability to recognize numbers in a small set, understand relationships between numbers and quantities, compare numbers, and identify, describe, and compare shapes (ECLKC, n.d). Therefore, it is imperative to introduce ideas such as number sense, representation, spatial sense, measurement, estimation, patterns, and problem-solving to preschoolers in order to help them develop early math skills (Diezmann & Yelland, 2000; Fromboluti & Rinck, 1999). Early education research suggests that preschoolers from higher socioeconomic status (SES) groups exhibit greater shape identification than preschoolers from lower SES groups (Bower et al., 2020a). These disparities are particularly concerning given the strong association between shape identification and mathematics learning (Bower et al., 2020a). Furthermore, studies on mathematics skill acquisition of young children show that first grade mathematics curriculum builds on arithmetic concepts such as understanding size, shape, and patterns, ability to count verbally, recognizing numerals, identifying more and less of a quantity, and understanding one-to-one correspondence, indicating that the development of advanced mathematics skills depends on early math foundations (National Research Council, 2001). This also suggests that it is critical to foster environments that promote developmentally appropriate outcomes in early mathematics learning. Current evidence in the field of early mathematics development supports this claim by demonstrating that prekindergarten children whose parents provide frequent operational numeracy activities at home perform better on arithmetic tests than their counterparts (Susperreguy et al., 2020).

To date, majority of studies addressing school readiness in the context of poor housing conditions among low-income families have focused on outcomes in socio-emotional and behavioral development. The purpose of the present review is to identify gaps in child development research on early math skills in the context of residential instability and suggest next steps to address inconsistencies in current literature on early childhood math education.

Search Procedure and Selection Criteria

This study is informed by a review of current literature on early childhood development in the context of residential instability. The current literature review only includes studies that were peer reviewed. Search engines and databases Google Scholar, ERIC-Education, Early Education CONNECTIONS, PsychInfo, and EBSCO Host were used to find relevant articles. Only those articles were included in this study that were published between 2001-2021. This date range was chosen due to the limited number of studies that have looked at housing instability from a developmental perspective. Search terms “early childhood”, “school readiness”, “early mathematics development”, “preschoolers’ mathematics development”, “residential instability”, and “housing instability” were used to distill studies across the abovementioned platforms. The search revealed 68 peer reviewed articles. Of these 68 articles, 20 have been included in the current review. These 20 articles were most relevant to the study of early childhood development and school readiness in the context residential instability, as well as early mathematics learning of preschool children. Studies were excluded if they were not peer reviewed, lacked focus on early childhood developmental period, lacked focus on early mathematics development and school readiness outcomes of preschool children (3-5 years), or did not define how they operationalized residential instability.

Overview of Current Review

The current set of literature was identified through the search procedure outlined above. Articles were read and summarized. Table 1, 2, and 3 in the appendix section summarize details of articles included in this review. Table 1 summarizes studies on residential instability in early childhood, table 2 summarizes studies on early mathematics development, and table 3 summarizes studies on residential instability and school readiness. The tables contain author and publication year, location,

methodology used, sample size and socio-demographic context of study sample, predictor and outcome variable(s) operationalized, and relevant results for each article included in this review.

As a body of literature, the current review reveals a number of trends in early childhood development research in the context of housing instability. Firstly, most of the studies were conducted in the United States (18). The remainder two studies were conducted in Malaysia (Omapak & Teng, 2021) and Chile (Susperreguy et al., 2020). Secondly, the variety of measures of residential instability used in studies in the current review set illustrate both the complexity and difficulty of generalizing understandings regarding the impact of housing instability on child development. Amongst the 9 articles looking at the implications of insecure housing on early childhood development and school readiness, about 13 different measures of residential instability were used. Only one of these measures was used in more than one study— frequent residential moves (used by Anderson et al., 2014; Molborn et al., 2018; Ziol-Guest & McKenna, 2014). Similarly, of the variety of indicators used across the 11 articles on early mathematics development in this review to measure mathematics literacy and knowledge of preschoolers, only 3 used Test of Early Mathematics Ability (TEMA) (used by Bower et al., 2020a; Fisher et al., 2012; Omapak & Teng, 2021). Most of the studies in this review (18 out of 20) used surveys, questionnaires, and pre-test post-test quantitative methods.

Thirdly, the current review also found differences and similarities in the socio-demographic characteristics of participants across studies. All articles in this review looked at male and female preschoolers. Except for five studies, all studies were conducted among participants who identified as White, Black, or Hispanic/Latino. These five studies (Bower et al., 2020a; Fisher et al., 2012; Purpura & Logan, 2015; Rittle-Johnson et al., 2019; Zippert et al., 2021) included Asian participants in addition to the race/ethnicities mentioned above. Most of the studies (15) did not clearly define their measurement of SES. Only 5 out of the 20 articles presented in this review include information on how SES was measured in their respective studies. Two articles looked at highest educational attainment of parent

caregiver(s) (Bower et al., 2020a; Bower et al., 2020b), two looked at household income level (Parks, 2020; Ziol-Guest & McKenna, 2014), and one looked at both parental education and relative income (Molborn et al., 2018).

Lastly, a number of articles drew from disciplines other than early childhood education. These disciplines included psychology, sociology, economics, and education more broadly. By drawing on ideas and methods from a variety of disciplines, broader conceptualizations of, and means of measuring residential instability, school readiness, and early mathematics literacy were evident.

Contributions of Current Review

Three main themes were identified across articles in this review, namely, residential instability in early childhood, early mathematics development, as well as residential instability and school readiness.

Residential Instability in Early Childhood

In the studies reviewed, the types of housing conditions had clear effects on outcomes in child development and wellbeing. Aspects of residential life studied included frequency of residential moves, physical quality of housing, crowding, home ownership, subsidized housing, housing unaffordability, and homelessness.

Anderson et al. (2014) found that frequent residential moves have the most detrimental implications for children kindergarten to fifth grade in terms of their engagement with family, peers, and neighborhood processes. Leventhal and Newman (2010) revealed similar findings suggesting that frequent residential moves have negative short-term associations with socioemotional development and schooling outcomes of young children. While Buckner (2008) found that experiencing homelessness

increased the risk of adverse outcomes in mental health, developmental status, and academic achievement among young children, they also suggested that this was not a universal finding.

Early Mathematics Development

Findings from studies on early mathematics development highlighted that preschoolers' early mathematics abilities are determined by individual factors (spatial skills, repeating patterning knowledge, executive functioning, developmental abilities, and gender) as well as environmental factors (game-based interventions, parental engagement in mathematics learning activities, quality of teacher-student interactions, and SES).

Bower et al. (2020a) found that preschoolers from higher SES and female preschoolers had higher spatial language comprehension compared with their lower SES and male peers, respectively. These findings are important given that spatial language comprehension is strongly associated with mathematics development (Bowler et al., 2020a). Additionally, this study also revealed that spatial language comprehension mediates the association between spatial skill and mathematics performance for female preschoolers only. Bowler et al. (2020b) built on these findings to suggest that spatial training can improve early spatial and math skill acquisition for low-income learners at the preschool level. Furthermore, Rittle-Johnson et al. (2019) showed that repeating patterning skills, which are related to young children's spatial skills, also predict math knowledge and growth of preschool children. Evidence from the field also suggests that preschoolers' repeating patterning knowledge can be improved through targeted instruction (Zippert et al., 2021). A study conducted among low-income children 3-5 years of age in New England, US, demonstrated the existence of a reciprocal relationship between math interest and math ability, such that high levels of early math interest were related to strong concurrent and later math skills (Fisher et al., 2012). In addition, Fisher et al. (2012) also revealed that math skills predicted math interest approximately 5 months later, even after controlling for initial interest and a

brief intelligence measure. Studies in this review also looked at the contribution of executive functioning skills to early mathematics literacy. Harvey and Miller (2017) suggested that inhibitory control and working memory make unique contributions to English and Spanish speaking children's early mathematics abilities in the domains of numeracy, arithmetic, spatial/geometric reasoning, and patterning/logical relations. Moreover, Schmitt et al. (2017) emphasized the bidirectional nature of the relationship between executive functioning in early childhood and mathematics outcomes in preschool.

The current review also revealed that studies on early mathematics learning had diverse perspectives on how preschool children's math abilities can be improved. Susperreguy et al. (2020) demonstrated that parents' knowledge of number-related games predicted children's arithmetic skills and growth in nonsymbolic number comparison. Where Omapak and Teng (2021) confirmed earlier findings that game based interventions improve preschoolers' performance in early mathematics, Parks (2020) suggested that the quality of teacher interaction with children who differ from each other in terms of race, temperament, gender, as well as other identity markers determine preschoolers' mathematics performance. Yet, Purpura and Logan (2015) indicated that different mechanisms may enhance mathematics acquisition of preschool children dependent on their developmental abilities.

Residential Instability and School Readiness

Studies concerning the impact of residential instability on young children's school readiness revealed that experiencing unstable housing, in any capacity, negatively affected preschoolers' readiness for school. These findings were consistent across studies in this review. It is important to note that these studies measured residential instability in a variety of ways, ranging from residential mobility, distance of move, quality of move, quality of housing, residential cost burden, housing condition, housing market value, public/subsidized housing, housing market distress event, and the extent of disadvantage rampant in a family's neighborhood.

Coley et al. (2013) found that children in families with higher-than-average levels of residential moves had greater internalizing and externalizing problems in comparison to children with fewer residential moves. Ziol-Guest and McKenna (2014) echoed these findings indicating that moving three or more times was associated with increased risk of internalizing and externalizing behaviors such as attention problems, anxiety, depression, aggressive tendencies, and hyperactivity among children 5 years of age. Studies also found significant associations between housing instability, executive functioning, and socioemotional outcomes of young children. Where Schmitt et al. (2015) found that frequent residential mobility was significantly and negatively associated with inhibitory control among preschool children, Molborn et al. (2018) revealed that high levels of housing related moves, changed neighborhoods, or moving to neighborhoods with lower SES predicted young children's socioemotional and behavior scores. Residential instability was also found to be negatively associated with the quality of home learning environments of preschoolers (May et al., 2018). This finding is important given that home numeracy environments have shown to predict children's early mathematics skills (Susperreguy et al., 2020). Coulton et al. (2016) emphasized findings from other studies in this section suggesting that children exposed to insecure housing have lower kindergarten readiness scores.

Although this review found that current literature in early childhood development and education lacks studies on the intersectionality between residential instability and early mathematics development, an overwhelming majority of the articles included in the current review indicate that housing instability negatively impacts developmental and schooling outcomes of young children. These findings suggest that access to safe and secure housing is an important social determinant of child development.

**Implications for Future Research Concerning Early Mathematics Development in the Context
of Residential Instability**

This literature review has important implications for early mathematics development research and practice in the context of poor housing conditions. Results from this review can be used to address the relationship between residential instability and early mathematics development of preschool children as it relates to school reading. To fully address the relationship between housing instability and mathematics learning outcomes of preschool children, future research must incorporate mediating and moderating factors that have been empirically shown to influence residential instability in early childhood and early math skills.

Future research looking at the impact of insecure housing in early childhood must also integrate relevant theoretical frameworks of child development to better operationalize the multitude of contexts that influence developmental trajectories of children, especially at-risk children. Researchers must also broaden the operationalization of residential instability to capture the complex nature of housing instability, especially in rural and global contexts. Future studies must utilize longitudinal and experimental study designs to strengthen internal and external validity of findings. More research and piloting efforts are needed to wholistically understand the impact of unstable residential conditions in early childhood on mathematics learning of preschool children.

Further studies must also embody an equity lens to reduce disparities in outcomes of early mathematics development. Given the importance of early math skills for later math outcomes, future research must closely examine numeral counting, shape recognition, patterning, representation, estimation, and problem-solving skills among preschoolers experiencing residential instability to reduce disparities in early math abilities. Research has shown that income poverty is an insufficient measure of economic hardship for children, and economic stressors for families can extend beyond income poverty to include material hardship, and subjective financial stress (Schenck-Fontaine & Panico, 2019). Research in this field must acknowledge the multidimensional nature of economic stress as it effects housing instability, and in turn young children's behavioral outcomes and school readiness (Palermo et

al., 2018). Studies in early learning and care must also avoid treating SES as a composite variable comprising of income, highest educational attainment, and race/ethnicity. Instead, studies should focus on social determinants that uniquely influence early development and education outcomes in their population of interest (American Psychiatric Association, 2007). Researchers in the field must also utilize an intersectional approach to capture experiences of racism and social prejudice instead of collecting information on race/ethnicity of children and their families. This shall help identify institutions and structures that systemically marginalize minority communities, and direct early education interventions and resources towards families and children who need it the most. Furthermore, early learning programs and policies must factor in socio-ecological contexts of preschoolers such as housing conditions to equitably improve outcomes in school readiness and early mathematics skill acquisition.

Limitations

The current review has certain limitations. Of the 20 articles included in the current literature review, only 2 used experimental study designs. A vast majority of the articles included in this review followed a survey design methodology.

There was also a lack of homogeneity in the measurement of residential instability across studies. For example, Ziolo-Guest and McKenna (2014) characterized housing instability in early childhood as families with children 0-5 years who experience frequent residential moves, whereas Coulton et al. (2016) used housing condition, housing market value, public/subsidized housing, housing market distress event, and neighborhood quality concentrated disadvantage to measure residential instability in their study population. This resulted in limited scope of comparison across studies.

This literature review only includes peer reviewed studies that look at insecure housing in early childhood and its implications for outcomes of school readiness, as well as peer reviewed articles on early mathematics development. The initial search found 96 studies, of which only 68 were peer reviewed. Of these 68, only 20 have been included in the current review. Studies were excluded if they

were not peer reviewed, lacked focus on early childhood developmental period, lacked focus on early mathematics development and school readiness outcomes of preschool children (3-5 years), or did not define how they operationalized residential instability. As a result, this exclusion criteria limited the number of studies that could be included in the current review.

The current literature review found that relatively limited research takes a developmental approach to studying the effects of housing instability. Only nine peer reviewed studies were found to assess the impact of residential instability on early childhood. However, of these studies, Buckner (2008) only examined homelessness as it relates to child development. Furthermore, of the 19 articles reviewed by Buckner (2008), only 5 focused exclusively on the implications of homelessness for preschoolers. The lack of studies on residential instability during the early childhood developmental period conducted in a rural setup also introduces biases and limitations to our understanding of what housing instability looks like in rural areas, and how it impacts young children's developmental and schooling outcomes in rural settings.

While this review found studies on early mathematics development that assessed preschoolers' numeral counting skills, patterning, spatial sense, and problem-solving skills, none of these studies looked at young children's representation, and estimation skills. It is important to note that out of the 11 studies on early mathematics learning that are included in this review, only 4 assessed problem-solving skills of preschool children (Bower et al., 2020a; Coley et al., 2013; Schmitt et al., 2017; Susperreguy et al., 2020). Except for Omapak and Teng (2021) and Susperreguy et al. (2020), all the studies presented in this review were conducted within the United States. This limits current understanding about early mathematics abilities of preschool aged children across diverse settings and cultures. Furthermore, this literature review did not find any articles that looked at the relationship between residential instability in early childhood and preschoolers' outcomes in early mathematics acquisition.

Conclusion

As this review has attempted to illustrate, residential instability in early childhood is a complex area of research. However, expansion of current research efforts in this area will yield benefits for young children and their families in the short term, and the economy in the long term. This review also demonstrates that the ways in which housing instability is measured is an important issue. While studies in this review examined unstable housing as a predictor of early childhood development and school readiness of preschool children, they employed a vast variety of indicators to measure unstable housing. This hinders comparison across studies and limits generalization of results. Child development researchers could potentially benefit from curating validated, standardized instruments of residential instability that pay close attention to the various components of, and factors behind insecure housing. These standardized instruments can allow researchers to look at specific elements of housing instability such as frequent residential moves, in particular contexts such as domestic violence or unsafe neighborhoods.

Similarly, this review acknowledges the general lack of uniformity in the way early mathematics development is operationalized across studies. By closely examining individual aspects of mathematics literacy such as numeral counting, shape recognition, geometrical and spatial sense, patterning, and problem-solving in the context of poor housing conditions, current evidence in preschoolers' math skills can be expanded in new directions.

In addition, this review argues that the quality of living arrangements has important implications for schooling outcomes of young children by highlighting articles on residential instability in early childhood, and housing instability as it relates to school readiness of preschoolers. Although there is evidence suggesting that housing instability has a detrimental effect on early childhood development and school readiness of young children, its implications on early math knowledge and abilities remains understudied. The goal of this review is to draw attention to the need to study mathematics

development of preschoolers who experience inadequate housing and encourage researchers in the field of early childhood education to critically examine access to housing as a social determinant of mathematics learning. By conducting an in-depth examination of the relationship between insecure residential arrangements and early mathematics literacy of preschool children, future research can bridge gaps in current literature that has failed to examine this relationship closely.

Findings from future research in this area can then inform early education programs and policies to treat housing instability as a risk factor for suboptimal outcomes in early mathematics at the preschool level. It is imperative to approach the study of residential insecurity as it relates to acquisition of skills in mathematics, from an equity perspective. In this capacity, this review advocates that early childhood education interventions and policies support equitable outcomes in mathematics learning for preschool children while paying special attention to how lack of adequate housing effects development of fundamental skills in mathematics.

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Appendix

Table 1

Residential Instability in Early Childhood

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable (s)	Outcome variable(s)	Relevant results
Anderson et al. (2014)	US	Examine the relation between residential mobility and children and adolescents' socio-emotional and academic development	Survey design: the study made use of NICHD Study of Early Child Care and Youth Development, 1997)	N = 1056 Age: early childhood (birth - 54 months of age) middle childhood (kindergarten to fifth grade) adolescence (sixth grade to 15 years of age) Race/ethnicity: White, African American, Hispanic Gender: Male, Female SES: N/A	Residential mobility of the family	Context indicators: family, neighborhood, peers, school	A limited number of significant associations were found between the neighborhood context and childhood residential mobility. Results indicated that middle childhood was a period when children's contexts may be the most likely to change concurrent with a residential move. Children who moved generally experienced lower quality contexts than children who did not

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable (s)	Outcome variable(s)	Relevant results
Buckner (2008)	US	This article summarizes findings on the effects of homelessness on children's mental health, developmental status, and academic achievement	Literature review Of quantitative studies	N = N/A Age: 0-18 years Gender: Male, Female SES: N/A	N/A	Child Behavior Checklist (CBCL), Children's Depression Inventory (CDI), Denver Developmental Screening Test (DDST), Diagnostic Interview Schedule for Children (DISC), Diagnostic and Statistical Manual of Mental Disorders (DSM-III-R), Kaufman Brief Intelligence Test (KBIT), Wechsler Individual Achievement Test-Screener (WIAT-S), Wechsler Intelligence Scale for Children-Revised (WISC-R), Wide Range Achievement Test-Revised (WRAT-R)	The overall pattern of findings across these studies suggests that more often than not, children's exposure to homelessness increases their risk of adverse outcomes. Nonetheless, this is not a universal finding, and differences in outcomes between homeless children and low-income children are not as pronounced as might be anticipated. The reasons for this are unclear

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable (s)	Outcome variable(s)	Relevant results
Leventhal and Newman (2010)	US	This article presents a critical review of recent research on the role of housing in children's development, including physical health; social, emotional, and behavioral outcomes; and schooling, achievement, and economic attainment	Literature review of quantitative studies	N = N/A Age: 0-18 years Gender: Male, Female SES: N/A	Physical housing quality, crowding, residential mobility, homeownership, subsidized housing, and housing Unaffordability	Children's physical health, socio-emotional development, behavioral outcomes, schooling, achievement, and economic attainment	The review sought to assess the current knowledge base on housing and children's development. A large, empirically sound body of research on mobility using diverse samples (including nationally representative ones) indicates that moving, especially multiple times, has negative short-term associations with children's and adolescents' schooling and social and emotional outcomes

Table 2*Early Mathematics Development*

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable (s)	Outcome variable(s)	Relevant results
Bower et al. (2020a)	US	The current study conducts a moderated mediation model to test the potential moderating effects of group factors, such as socioeconomic (SES) status and gender, on the possible mediation of spatial language comprehension on the association between spatial skill and mathematics performance	Pre-test post-test: A subset of the pretest assessments was examined for this study, namely, Spatial Language Comprehension Task, Woodcock–Johnson-IV Applied Problems subtest, Test of Early Mathematics Ability, subtest, 2D and 3D TOSA, and the Woodcock–Johnson-IV Picture Vocabulary subtest	N = 192 Age: 3 years Race/ethnicity: White, Black, Hispanic/Latino, Asian, Other Gender: Male, female SES: Educational attainment of primary caregiver	Vocabulary: WJ-PV Spatial language comprehension: Spatial Language Comprehension Task Spatial skills: 2D and 3D TOSA Expressive vocabulary: Woodcock–Johnson-IV Picture Vocabulary subtest Gender: male, female SES: educational attainment of primary caregiver	Math skills: Test of Early Mathematics Ability subtest, and the Woodcock Johnson-IV Picture Vocabulary subtest	The results indicate that the novel Spatial Language Comprehension Task is a reliable measure for examining group differences and the early space–math link. Specifically, higher-SES preschoolers and females had higher spatial language comprehension than their lower-SES peers and males, respectively. Additionally, spatial language comprehension mediated the association between spatial skill and mathematics performance for females only

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable (s)	Outcome variable(s)	Relevant results
Bower et al. (2020b)	Northeastern US	The current study tested (a) whether spatial training benefited preschoolers' spatial and mathematics skills, (b) if the type of feedback provided during spatial training differentially influenced children's spatial and mathematics skills, and (c) if the spatial training's effects varied by socioeconomic status (SES)	Experimental: Children were recruited from Head Start facilities as well as private preschools in two U.S. northeastern states. Preschoolers were randomly assigned to either a 'business-as-usual' control or one of three spatial training groups (modeling and feedback [MF]; gesture feedback [GF]; spatial language feedback [SLF]).	N = 187 Age: preschool aged children Race/ethnicity: White, Black, Hispanic/Latino, Other Gender: Male, female SES: Educational attainment of primary caregiver	Spatial skill training: shape parade, spatial assembly training conditions: MF condition, GF condition, SPF condition SES: educational attainment of primary caregivers	Spatial skills: 2D TOSA, 3D TOSA, spatial vocabulary assessment Mathematics: shape identification test, WJ-AP, TEMA-3	Results indicate that first, any spatial training improved preschoolers' 2D TOSA performance, although a significant interaction with SES indicated improvement was driven by low-SES children. Furthermore, low-SES children showed greatest gains on the 2D TOSA with MF and GF. Second, MF and GF improved low-SES children's performance on the 3D TOSA. Third, only low-SES children with MF saw improvements in far-transfer to mathematics (Woodcock-Johnson: Applied Problems, but not the Test of Early Mathematical Ability). Results indicate that, especially for low-income learners, spatial training can improve children's early spatial and mathematics skills

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable(s)	Outcome variable(s)	Relevant results
Fisher et al. (2012)	New England, US	The current study investigated the relationship between math interest and ability in a low-income, diverse group of preschool children. First, we predicted that early math interest would predict concurrent math skills. Second, we hypothesized that early math ability would predict math interest at later assessment. Third, we similarly hypothesized that early math interest would predict later math skills.	Pre-test post-test: Children were assessed on measures such as TEMA-2, Early Inventory Screening-Revised (EIS-R) language and cognition subtest, and interest observations in late fall/winter (Time1) and spring (Time 2), with an average of 5 months between assessments	N = 118 Age: 3-5 years Race/ethnicity: White, Latino, African American, Asian, Other Gender: Male, Female SES: N/A	Interest observations: time played, enjoyment global, goal-directed play, teacher report of child interest	TEMA-2, EIS-2 language, and cognition subtest	Analyses of concurrent relationships indicated that high levels of interest were related to strong math skills. Even when controlling for initial interest and a brief intelligence measure, math skills predicted math interest approximately 5 months later; in the same way, early interest predicted later skill, even controlling for initial interest. These findings suggest that a reciprocal relationship between math interest and math ability may be in place as early as preschool

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable (s)	Outcome variable(s)	Relevant results
Harvey and Miller (2017)	US	The contribution of 3 executive function skills (shifting, inhibitory control, and working memory) and their relation to early mathematical skills was investigated with preschoolers attending 6 Head Start centers	English and Spanish speaking children were assessed for the executive function skills as well as their receptive vocabulary skills and early mathematical abilities using the Child Math Assessment which captures an array of skills across 4 domains	N = 92 Age: 3-5 years Race/ethnicity: N/A Gender: Male, Female SES: N/A	Executive function skills: shifting, inhibitory control, and working memory Receptive vocabulary skills Language: English-only vs dual language learners	Early mathematics ability: numeracy, arithmetic, spatial/geometric reasoning, and patterning/logical relations	Hierarchical regression analyses revealed that inhibitory control and working memory made unique contributions to children's early mathematical abilities in the domains of numeracy, arithmetic, spatial/geometric reasoning, and patterning/logical relations after we controlled for age, receptive vocabulary, and previous Head Start experience. Furthermore, receptive vocabulary also accounted for significant variance in children's early mathematical abilities above and beyond executive function skills. No group differences emerged between English-only and dual language learners on the fit of the regression models

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable (s)	Outcome variable(s)	Relevant results
Omapak and Teng (2021)	Menggatal district, Sabah, Malaysia	This study examined whether game-based interventions to facilitate early mathematics learning among preschoolers lead to improvement in their mathematical abilities	Pre-test post-test: A single group pre-test and post-test with intervening Early Mathematics based games was used in this research. Preschoolers had taken a pre-test at baseline before the start of intervention program. The post-test was given at the end of the intervention program. Meanwhile, inferential analysis involved paired sample t-test to identify the significant difference between the pre and post-test	N = 100 Age: 5-6 years Race/ethnicity: N/A Gender: Male, Female SES: N/A	Intervention program: Learning Mathematics through games	Early math abilities: TEMA	The results of this study indicate that the use of games as intervention can serve as an effective tool to improve the preschoolers' early mathematics performance and develop their interest in learning through games. This study confirmed earlier findings that game based interventions improve preschoolers' performance in early mathematics

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable (s)	Outcome variable(s)	Relevant results
Parks (2020)	US	Drawing on a 3-year interpretive study that followed a cohort of children from prekindergarten to Grade 1, this article presents results of a multiple case study, which demonstrated that although two children had the same teachers, classmates, and curricula over 3 years, their experiences in the three successive mathematics classrooms were quite different from each other	Qualitative research: this is a longitudinal multiple case study that aimed to follow two children over 3 years of schooling, using similarities and differences in the two children's participation in typical mathematics classrooms to understand how their mathematical identities were constructed over time	N = 2 Age: 3-5 years (prekindergarten children followed for 3 years) Race/ethnicity : Black Gender: Male, Female SES: Low-income	-	-	This study suggests that descriptions of classrooms that focus on the teachers' interactions with multiple children will not always adequately convey the quality of mathematics instruction experienced by individual children. This study contributes to growing understandings of the relationships between mathematical identity and learning. Broadly, this study suggests that researchers and teacher educators need to attend not just to teachers' classroom practices with "children," but to the ways that they engage with <i>particular</i> children who differ from each other in a variety of ways including race, temperament, gender, as well as other identity markers

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable (s)	Outcome variable(s)	Relevant results
Purpura and Logan (2015)	US	Both mathematical language and the approximate number system (ANS) have been identified as strong predictors of early mathematics performance. Yet, these relations may be different depending on a child's developmental level. The purpose of this study was to evaluate the relations between these domains across different levels of ability	Pre-test post-test: Children were assessed on tasks on early numeracy, vocabulary, executive functioning, mathematical language, and approximate number system in the fall and spring of the academic year. In the spring, early numeracy was used as a dependent variable. Two separate sets of analyses were conducted—conventional linear regressions, and quantile regressions	N = 114 Age: 3-5 years Race/ethnicity: White, African American, Hispanic, Asian, Other Gender: Male, Female SES: N/A	The Preschool Early Numeracy Skills Test (PNS-B) over fall, Definitional Vocabulary subtest of the Test of Preschool Early Literacy Skills, Author-developed measure of mathematical content language, Pana math test, Stroop-like task, Dimensional Change Card Sort task, and listening recall task from the Automated Working Memory Assessment, Age, sex, parental education, and rapid automatized naming (RAN)	Early Numeracy: The Preschool Early Numeracy Skills Test—Brief Version (PNS-B) over Spring	The mixed-effect regressions indicated that mathematical language, but not the ANS, nor other cognitive domains, predicted mathematics performance. However, the quantile regression analyses revealed a more nuanced relation among domains. Specifically, it was found that mathematical language and the ANS predicted mathematical performance at different points on the ability continuum. These dual nonlinear relations indicate that different mechanisms may enhance mathematical acquisition dependent on children's developmental abilities

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable(s)	Outcome variable(s)	Relevant results
Rittle-Johnson et al. (2019)	US	<p>This study focused on patterning and spatial skills.</p> <p>Hypotheses:</p> <ol style="list-style-type: none"> 1. Repeating patterning skills and spatial skills are moderately correlated 2. Spatial skills predict math knowledge, both concurrently and seven-months later 3. Repeating patterning skills predict math knowledge, both concurrently and seven-months later 4. Spatial and repeating patterning skills predict later math knowledge 	<p>Pre-test post-test: Within the first quarter of the school year, children were assessed at their preschools in two 30-min sessions approximately five days apart. The first session included assessments of verbal ability, research-based patterning, form perception, and spatial visualization. In the second session, children completed assessments of visual-spatial and verbal WM, math knowledge, and teacher-based patterning. At Time 2, children completed the math and verbal STM and WM assessments</p>	<p>N = 73 Age: 4-5 years Race/ethnicity: White, African American, Hispanic, or Latino, Asian or Pacific Islander, Other Gender: Male, Female SES: N/A</p>	<p>Repeating patterning skills: Research based patterning assessment, teacher-based patterning assessment Spatial skills: Form perception, spatial visualization, visual-spatial working memory Control variables: Age at Time 1, verbal ability, verbal short-term and working memory</p>	<p>Math knowledge: Research based Mathematics Assessment (REMA) short form</p>	<p>Children's repeating patterning and spatial skills were related and were each unique predictors of children's math knowledge at the same time point and seven months later. Further, repeating patterning skills predicted later math knowledge even after controlling for prior math knowledge. Thus, although repeating patterning and spatial skills are related, repeating patterning skills are a unique predictor of math knowledge and growth</p>

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable(s)	Outcome variable(s)	Relevant results
Schmitt et al. (2017)	Pacific Northwest, US	This study hypothesized that EF would significantly predict math in preschool and kindergarten, and that math would predict math during this time frame. Further, we expected that EF and math growth trajectories would be correlated	Pre-test post-test: The present study explored the bidirectional and longitudinal associations between executive function (EF) and early academic skills (math and literacy) across 4 waves of measurement during the transition from preschool to kindergarten using 2 complementary analytical approaches: cross-lagged panel modeling and latent growth curve modeling (LCGM)	N = 424 Age: 4-5 years Race/ethnicity : N/A Gender: Male, Female SES: N/A	EF: Head–Toes–Knees–Shoulders (HTKS) task, a Card Sort task, the Auditory Working Memory subtest from the Woodcock–Johnson III Tests of Cognitive Abilities, and the Simon Says task	Academic Achievement: Literacy skills were assessed with the Letter-Word Identification subtest from the Woodcock–Johnson III Tests of Achievement, math skills were assessed with the Applied Problems subtest from the Woodcock–Johnson III Tests of Achievement	Cross-lagged panel models indicated bidirectional relations between EF and math over preschool, which became directional in kindergarten with only EF predicting math. Moreover, there was a bidirectional relation between math and literacy that emerged in kindergarten. Similarly, LGCM revealed correlated growth between EF and math as well as math and literacy, but not EF and literacy. Exploring the patterns of relations across the waves of the panel model in conjunction with the patterns of relations between intercepts and slopes in the LGCMS led to a more nuanced understanding of the relations between EF and academic skills across preschool and kindergarten

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable (s)	Outcome variable(s)	Relevant results
Susperreguy et al. (2020)	Chile	This study investigated the longitudinal associations between children's early mathematics and their home numeracy environment (HNE)	Pre-test post-test: Chilean children from families who varied widely in socioeconomic status were assessed at the beginning and end of prekindergarten	N = 419 (beginning of kindergarten); 368 (end of kindergarten) Age: 4-5 years Race/ethnicity : N/A Gender: Male, Female SES: N/A	Activities : Code, meaning, mapping, operations, games Parent: Literacy attitudes, literacy expectations, numeracy attitudes, numeracy expectations	Literacy T3: letter word identification, vocabulary Numeracy T3: number comparison (symbolic), number comparison (nonsymbolic), arithmetic fluency, number line, applied problem solving	Children whose parents provided frequent operational numeracy activities (e.g., learning simple sums) at prekindergarten showed better arithmetic performance and growth in nonsymbolic and symbolic number comparison at the end of kindergarten. Parents' knowledge of number-related games predicted children's arithmetic skills and growth in nonsymbolic number comparison. These findings underscore the persistent relations between the HNE and the development of children's mathematical skills

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable (s)	Outcome variable(s)	Relevant results
Zippert et al. (2021)	US	The purpose of the current study was to examine the causal effects of repeating patterning and numeracy tutoring on repeating patterning, numeracy, and general mathematics knowledge in the year before kindergarten	Experimental: Children's general math and numeracy, successor, and patterning knowledge were first assessed in a 30-min session. Next, participants were randomly assigned to one of three conditions (i.e., business-as-usual (BAU) Control, Patterning + Numeracy, or Literacy + Numeracy). Participants in each tutoring group received five 30-min sessions of instruction in pairs. Following the completion of tutoring, all participants were post tested	N = 211 Age: 4-5 years Race/ethnicity : White, African American, Hispanic, Asian Gender: Male, Female SES: N/A	Patterning knowledge: teacher-based patterning assessment (TBP), research-based patterning assessment Successor and predecessor knowledge: measured using an adapted version of the unit task. The authors added new items to measure predecessor knowledge with small set sizes. Conditions: Patterning + Numeracy, Literacy + Numeracy, Control	General math and numeracy knowledge: REMA short form	The present study examined the effects of combining patterning and numeracy tutoring on preschoolers 'repeating patterning, numeracy, and general mathematics knowledge in comparison to numeracy tutoring without patterning tutoring and regular classroom instruction. The authors obtained causal evidence that preschoolers 'repeating patterning knowledge can be improved through targeted instruction. However, neither this tutoring nor our other numeracy tutoring condition led to significant improvements in specific or general measures of numeracy and mathematics knowledge compared with regular classroom instruction.

Table 3*Residential Instability and School Readiness*

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable (s)	Outcome variable(s)	Relevant results
Coley et al. (2013)	US	This study assessed housing quality, stability, type (i.e., ownership status and subsidy status), and cost simultaneously to delineate their unique associations with children's development	Survey design: This study used a representative, longitudinal sample of low-income children and adolescents from low-income urban neighborhoods from the Three-City Study	N = 2437 Age: 2-21 years Race/ethnicity: European American, African American, Hispanic, Other Gender: Male, Female SES: N/A	Physical quality, residential instability, housing type, housing cost, psychological distress, parenting stress, family routines, marital status, number of household members, maternal employment status, whether receiving TANF, child's age, gender, mothers' race/ethnicity, immigrant status, education, and each family's city of residence	Child and adolescent functioning: CBCL Internalizing & Externalizing scale Woodcock-Johnson Psycho-Educational Battery Revised (WJ-R) Letter-Word Identification and Applied Problems subtests to reading and math skills	Residential instability showed significant associations with children's emotional, behavioral, and cognitive functioning. Children in families with high levels of moves had greater internalizing and externalizing problems compared to children with fewer moves. These associations were mediated by maternal psychological distress in families with greater residential instability. These results might reflect the effects of single residential moves on short-term shifts in child functioning versus cumulative impacts of more long-term instability

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable (s)	Outcome variable(s)	Relevant results
Coulton et al. (2016)	Cleveland, Ohio, US	This study had four main hypotheses. 1. Exposure to poor quality housing and disadvantaged neighborhoods during early childhood negatively affect early literacy skills. 2. Housing market distress contributes to children's performance on early literacy. 3. Child maltreatment, residential instability and lead poisoning are negatively associated with early literacy. 4. Problematic housing conditions contribute to the likelihood of child maltreatment, residential instability, and lead poisoning	Survey design: This study draws on data from the ChildHood Integrated Longitudinal Data (CHILD) system and a geographic information system (GIS) based tool	N = 13,762 Age: Preschool aged children Race/ethnicity : Non-hispanic Whites, African American, Hispanic, Other Gender: Male, Female SES: N/A	Housing characteristics: housing condition, housing market value, public/subsidized housing, housing market distress event, neighborhood quality concentrated disadvantage Family characteristics: Teen mother, mother's education, poverty status Child characteristics: Low birth weight, gender, age, race/ethnicity, language, disability	Kindergarten readiness of literacy score	Children exposed to problematic housing and disadvantaged neighborhoods have lower kindergarten readiness scores. The negative effects of housing problems on kindergarten readiness are partially mediated by child maltreatment incidences, residential instability, and elevated blood lead levels

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable(s)	Outcome variable(s)	Relevant results
May et al. (2018)	Philadelphia, Pennsylvania, US	This study examined the effects of neighborhood concentrated disadvantage and neighborhood residential instability on the home physical environment and home learning environment for preschoolers in poor families	Questionnaire/Survey design: Participants were recruited from agencies that provide services to disadvantaged populations (i.e., day cares, Head Start) and agencies that are contracted to provide parenting services to families involved with child protection. Study measures were administered by trained interviewers during three interview sessions in the mothers' homes.	N = 187 Age: Preschool aged children Race/ethnicity: Non-Hispanic Whites, White Hispanic, African American, Other Gender: Male, Female SES: N/A	Demographic information: family, number of years lived in current neighborhood Concentrated disadvantage and residential instability, Perceptions of neighborhood disorder, Maternal depressive symptoms, Neighborhood social embeddedness,	Learning environment for preschoolers, physical environment for preschoolers	Results showed that concentrated disadvantage was negatively associated with the quality of the home physical environment, and residential instability was negatively associated with the quality of the home learning environment. Concentrated disadvantage had an indirect effect on the home learning environment through mothers' perceived neighborhood disorder and depressive symptoms. This effect was buffered by mothers' neighborhood social embeddedness.

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable (s)	Outcome variable (s)	Relevant results
Molborn et al. (2018)	US	This study examines the consequences of residential mobility for socioemotional and cognitive kindergarten readiness	Survey design: This study used data from the Early Childhood Longitudinal Study-Birth Cohort, a nationally representative longitudinal survey that followed U.S. children born in 2001 from infancy to kindergarten	N = 5050 Age: 0-5 years Race/ethnicity: Non-Hispanic White, African American, Hispanic, Other Gender: Male, Female SES: Parental education, Income to needs ratio	No. of residential moves, move distance, move quality, mother's marital status at birth, mother's educational attainment, whether child was born to a teen parent, other children in the household, household's income to needs ratio	ECLS-B construct ed socio-emotional functioning scale, externalizing behavior, social behavior, approach es to learning	By operationalizing residential mobility in different ways, our analyses discovered that residential mobility predicted young children's socioemotional behavior scores only when they experienced high levels of mobility, changed neighborhoods, or moved to a neighborhood with lower SES. Measures of the neighborhood-, family-, and child level selection of children into residential mobility partially explained the initially negative relationships between mobility and behavior scores. This held true across all dynamic measures of residential mobility: total number of moves, nonlinearity of move counts, move distance, and neighborhood quality of moves

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable (s)	Outcome variable(s)	Relevant results
Schmitt et al. (2015)	US	This study investigated the direct effects of residential mobility on children's inhibitory control and academic achievement during the fall and spring of a preschool year	-	N = 359 Age: Preschool age children Gender: Male, Female SES: N/A	-	-	Residential mobility was significantly and negatively associated with fall inhibitory control and fall math and literacy. Significant indirect effects of mobility were found for spring math and literacy through inhibitory control and fall achievement. Specifically, the negative relation between mobility and spring math and literacy was partially explained by lower scores on fall inhibitory control and academic skills

Authors & publication year	Location	Objective	Methods	Sample size; socio-demographic of the sample	Predictor variable (s)	Outcome variable(s)	Relevant results
Ziol-Guest and McKenna (2014)	US	This study assesses the consequences of housing instability on children's language, literacy, and behavioral problems at age 5	Survey design: The study made use of data from Fragile Families and Child Wellbeing Study a longitudinal, representative study of children born in 20 large U.S. cities between 1998 and 2000. As part of this dataset, parents were interviewed shortly after the birth of their children, then again by phone when the children were 1, 3, and 5; in-home assessments were done when the children were 3 and 5	N = 2810 Age: 0-5 years Gender: Male, Female SES: At or below Federal Poverty Line (FPL)	Frequency of residential moves among families with children 0-5 years	Language, literacy, and behavioral problems at age 5	Moving three or more times was not related to the children's language and literacy outcomes. But children who moved three or more times had more attention problems, anxiousness or depression, and aggressiveness or hyperactivity at age 5 than those who had never moved or those who had moved once or twice. These increases in behavior problems occurred only among poor children, the study found, suggesting that frequent moves early in life are most disruptive for the most disadvantaged children

