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Deposited in *Repositório ISCTE-IUL*:
2024-01-18

Deposited version:
Accepted Version

Peer-review status of attached file:
Peer-reviewed

Citation for published item:

Ribeiro, L., Donolato, E., Aguiar, C., Correia, N. & Zachrisson, H. (2024). Concurrent and longitudinal associations between parent math support in early childhood and math skills: A meta-analytic study. Journal of Cognition and Development. 25 (1), 66-99

Further information on publisher's website:
10.1080/15248372.2023.2248259

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Concurrent and Longitudinal Associations between Parent Math Support in Early Childhood and Math Skills: A Meta-Analytic Study

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Abstract

The aim of this study was to summarize evidence about the relations between parent math support in children aged 3 to 5 years (from several countries in America, Asia, and Europe) and concurrent and longitudinal math outcomes. The (bio)ecological model of human development guided our hypotheses. The design and reporting of this meta-analysis used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). We screened 2,163 abstracts, from which 135 full-text studies were assessed for eligibility. Forty-five studies fulfilled our inclusion criteria and were retained (representing 244 effect sizes); 90 studies were discarded as they did not include preschool children or measures of both parent math support and children's math skills. Meta-analysis using Correlated and Hierarchical Effect (CHE) models showed a significant positive association between parent math support and child math skills for both concurrent and longitudinal studies. On average, higher parent math support was associated with better maths skills in children, albeit these being small effect sizes. We found non-significant or inconclusive moderator effects related to formal vs. informal parent math support, type of children's math skills, participants' characteristics (e.g., child age, child/parent gender), parent education, and study characteristics. There was a significant moderator effect of the specificity of parent math support, with global assessments showing higher correlations with math outcomes than specific assessments. The publication bias analysis showed small-study effects for longitudinal but not for concurrent studies. Conclusions are drawn regarding the importance of promoting parent math support and informing future intervention studies.

Concurrent and Longitudinal Associations between Parent Math Support in Early Childhood and Math Skills: A Meta-Analytic Study

The importance of early mathematical skills in child development has been widely acknowledged and there is evidence of a strong link between these skills and later mathematical achievement, namely in US children (e.g., Hubbard et al., 2005; Mix & Cheng, 2012; Verdine et al., 2017). Math experiences and competencies prior to school entry are one of the most powerful predictors of later school success (Duncan et al., 2007). Math competence in childhood is also a strong predictor in the pursuit of and success in STEM (Science, Technology, Engineering, and Math) careers (Wai et al., 2009), contributing to economic benefits for individuals and societies (U.S. Department of Education, 2016). Indeed, early mathematical abilities, like spatial and numeracy skills, acquired before school age are steppingstones for future math skills and delays in the preschool years have an impact on future development (Ginsburg et al., 2008). Relatedly, cross-disciplinary research over the last decades has focused on the importance of early childhood for subsequent development, emphasizing the relevance of investments and stimulation in the early years (e.g., Heckman, 2006; Shonkoff & Phillips, 2000).

The aim of this meta-analysis was to investigate whether parent math support is a predictor of math outcomes, as this knowledge can inform parent practices and influence their impact on children's math success at school. Parent math support can be conceptualized as the proactive engagement of parents in various behaviors aiming to promote the learning and development of their children's math abilities. In this meta-analysis, we focus on parent support of math activities, broadly defined as the *frequency* with which parents support mathematical thinking through their interactions with their children (Levine et al., 2019) and the type of activities they use to reach that goal. Parents' support may be delivered through formal (i.e., didactic) and informal (i.e., child-centered, play-based) math activities and materials/resources (e.g., LeFevre et al., 2009; Ramani & Siegler, 2014).

This work is framed within the ecological systems theory (Bronfenbrenner, 1979) and the bioecological model of human development (Bronfenbrenner & Morris, 2006), which builds on the properties of *Process*, *Person*, *Context*, and *Time*, and has informed previous studies of early childhood math development (e.g., Perry & Dockett, 2018). In our meta-analysis, home math support is conceptualized at the *microsystem* level, entailing direct interactions between parents and children, with parents directly influencing children's math skills through engagement with math-related materials and activities. At this level, we also find parent education, which influences how resourceful parents can be in supporting math learning (e.g., Ashiabi et al., 2015; Tudge et al., 2009). Hence, features of early parent math support constitute proximal **Processes** (within the *microsystem*) that drive the development of children's math skills over **Time**. Further, we assume that this association is influenced by the developing child's individual characteristics like age and by both child and parent gender (i.e., **Person**), which have been shown to moderate the association between parent math support and math outcomes (e.g., Yildiz et al., 2020). Finally, Process and Person effects, and the interactions among them, are embedded in the children's immediate **Context** (at the *microsystem* level) (see Figure 1).

The Relation Between Parent Math Support (*Process*) and Children's Math Skills Over *Time*

When compared to other developmental and learning domains such as language and literacy, substantially less research has focused on the home predictors of (early) math competence (Elliott & Bachman, 2018b; Levine et al., 2019). Nevertheless, there is evidence supporting the role of young children's family home as a key early childhood setting in young US children's math outcomes (e.g., Crosnoe et al., 2010). Importantly, available evidence documents the primacy of the home environment for supporting children's developmental outcomes, including math (Ma et al., 2016; NICHD, 2005). The Home Math Environment (HME) is a construct created to describe mathematics-related activities children engage in with their parents, which are significant predictors of children's broad mathematics skills (e.g., encompassing specific skills such as numeracy, geometric reasoning, and spatial skills) (Blevins-Knabe & Musun-Miller, 1996; LeFevre et al., 2009; Kleemans et al., 2012; Levine et al., 2012; Niklas & Schneider, 2014; Hart et al., 2016; Zippert & Rittle-Johnson, 2018). In this meta-analysis, we focus on the role of parent-child math activities, more specifically, those related to spatial and numeracy skills. Previous studies on parents' contributions to math development have also elected numeracy and spatial abilities as the most relevant in terms of their predictive role for school math outcomes, for young US and Norwegian children (e.g., Elliot & Bachman, 2018a; Lehrl et al., 2020; Lombardi et al., 2017; Ribeiro et al., 2020).

The importance of numeracy skills for Canadian children's mathematical competencies has been emphasized by LeFevre et al. (2009). In their study, the frequency of activities indirectly connected to numbers such as playing dice games was weakly but significantly correlated with mathematical competencies at school enrolment. They concluded that Canadian children who are exposed to more number activities and materials at home show better mathematical skills later in school. Numeracy skills in early ages encompass a wide range of different competencies including counting abilities, number comparison, one-to-one correspondence (cardinality), and so on (Kleemans et al., 2012). Early numeracy skills, namely the ability to count, have been found to be associated with later math skills (Aunio & Niemivirta, 2010; LeFevre et al., 2006), in Finnish and Canadian children. Spatial skills in early childhood can be practiced in a range of tasks such as labelling spatial features of objects, including size, shape, and orientation (e.g., puzzle play, shape sorter); and engaging in play activities with materials such as block building, Lego, and board games (e.g., Elliott & Bachman, 2018b; Levine et al., 2019; Zippert & Rittle-Johnson, 2018).

There is mounting evidence that parent math support in early childhood has long term effects that can benefit children throughout childhood. Skwarchuk et al. (2014), for example, found that parent reports of formal home numeracy activities (e.g., teaching sums) were a predictor of Canadian children's symbolic number knowledge, whereas reports of informal activities (e.g., board games) predicted children's non-symbolic arithmetic skills. Other studies suggest that formal math practices may be more strongly associated with Canadian and Greek children's math skills as measured with formal instruments to assess global math skills (e.g., LeFevre et al., 2010; Manolitis et al., 2013) and that informal activities may promote specific types of math skills, such as counting, in US samples (Ramani et al., 2015). In fact, available evidence yields inconsistent findings on the associations between these dimensions of parental math support and children's math-related outcomes (see Elliott & Bachman, 2018b). One possible reason is that formal and informal activities are not always defined consistently across studies, possibly because theoretical models describing formal and informal math activities rely often on empirical methods (e.g., data reduction through exploratory factor analysis) (Elliot & Bachman, 2018a). Little attention has been paid to the developmental effects of formal vs. informal home numeracy practices, although preliminary evidence suggests that formal activities could be more predictive of math skills for older US children (Thompson et al., 2017).

There are two major types of research conducted in this area: studies relying on parent self-report and observational studies. The first and largest literature involves reports of parent support based on the type of materials and activities provided to the child in the home environment that relate to math skills (e.g., DeFlorio & Beliakoff, 2015; Missall et al., 2015). In this line, parental questionnaire studies were the primary focus of this meta-analysis. The second major category of literature in this field involves observational assessments of parent-child interactions (either at home or in the lab) related to a specific math skill (e.g., observations of parents and children playing a math-related game or activity) and identifying the key factors in the dyad dynamic that predict children's math skills. Although this type of research is less frequent, a few recent studies have used this approach (e.g., Susperreguy & Davis-Kean,

2016) and, therefore, they were included in our meta-analytic review, whenever they fulfilled the inclusion criteria. Furthermore, some of these observational studies examine the quality of math support (rather than the typical frequency of different types of math support, present in self-report questionnaires). Therefore, both quantity and quality ratings of math support were included in this study.

Moderation by *Person* Characteristics: The Role of Child Age and Child and Parent Gender

Previous studies on the associations between parent math support and children's math outcomes have found larger effects for younger children (e.g., Daucourt et al., 2021). For example, Dunst et al. (2017) found that the correlation between the math home environment and European and North American children's math achievement was almost three times higher for preschool children (3-4 years) than for those in kindergarten (5 years). Therefore, we need to examine the moderator role of children's age because although we examined the exposure variable (parent math support) at preschool ages, there is still variation in children's ages among selected studies that must be taken into account.

Moreover, both parent and child gender have frequently been addressed as important moderators in studies of parent math support and math outcomes. Most of the research in this area has focused on mothers as informants (e.g., Casey et al., 2018), with mothers reporting on their own interactions with their children. Mothers' reports on home numeracy activities (when compared to reports from both parents) have been found to show stronger associations with math skills (e.g., Yildiz et al., 2020). We are not aware of studies focusing on the differences between mothers' and fathers' reports of math support in the home. However, when it comes to the general home learning environment, it has been found that although parents' practices make unique contributions to preschoolers' academic skills, it is so only when the mother has less than a bachelors' degree. When the mother has completed her bachelor degree, fathers' practices are no longer a significant predictor of child achievement (Missall et al., 2015).

There are studies showing that boys outperform girls in some math-related outcomes as early as preschool and first grade (e.g., Levine et al., 2016; Wei et al., 2015), and throughout schooling (Reilly et al., 2015). However, this advantage is seen mostly in specific domains such as spatial processing (e.g., Halpern et al., 2007), with findings being inconsistent for more traditional tasks of basic numerical processing: some studies show no gender differences (e.g., Rosselli et al., 2009), some favor boys (e.g., Krinzinger et al., 2012), and others favor girls (Wei et al., 2012). Hutchison et al. (2019), in a study with the methodological advantage of combining frequentist and Bayesian models, used a large sample of boys and girls and found no evidence of gender differences for most domains (except for number-line tasks). The authors highlighted that parents' and teachers' stereotypes that boys are more likely to succeed in math than girls continue to affect children's attitudes toward math and maintain the gender gap in the pursuit of STEM careers, despite no evidence of real gender differences.

Relatedly, the role of parents in encouraging math activities differentially with boys and girls, either through formal instruction or through shared activities, has also been found to be a differentiating factor in terms of parent math support. Spatial and numeracy input is more commonly directed at boys than girls (Baenninger & Newcombe, 1995). More recently, Moffatt et al. (2009) found that parents, in the context of playing a board game, modeled mathematical procedures to the same extent for girls and boys (e.g., parent draws child attention to numerals) but prompted boys nearly twice as much to complete mathematical procedures (e.g., parent prompts the child to count aloud). We have not found any studies looking at the effect of parent-child dyad combinations (e.g., mother-son; father-daughter). However, in a study examining mothers talk to their 22-month-old US children about cardinal number, there was significantly more number-specific language input in mother-boy dyads than in mother-daughter dyads (Chang et al., 2011).

Moderation by *Context*: Parental Education as an Indicator of Family Socioeconomic Status

A key feature of the bioecological model is that micro-level processes are embedded in a wider ecological context. In the literature on parent math support, the most common context-level factor studied is the socioeconomic status (SES) of the family. Specifically, the hypothesis often proposed (e.g., Ribeiro et al., 2019) is that parent education (commonly used as a sole indicator of SES) is indicative of the wider human capital of the family environment, encompassing levels and forms of parental investments, priorities, and aspirations.

There is a steep and pervasive SES gradient in math achievement throughout early childhood that may be explained by differences in experiences both in the early childhood educational context and in the home environment (e.g., Burchinal et al., 2008; Gustafsson et al., 2011). Parent characteristics have been pointed out as one factor contributing to inequality even before school starts (DeFlorio & Beliafoff, 2015). For example, parents' practices have been found to have an important role in the association between SES and math learning in early childhood (see Elliott & Bachman, 2018a). In fact, one way (besides parent IQ) through which parent SES affects experiences with math in early childhood, is parent math support. Examining parent math support is, thus, of particular importance in understanding the relation between parent SES and early mathematical development (DeFlorio & Beliafoff, 2015).

There is evidence of home-based parent involvement in math-related activities differing as a function of SES, and more specifically, as a function of parent education. For example, US mothers with higher levels of education have been found to offer better cognitive support to their children (e.g., Neitzel & Stright, 2004). Further, HME was found to explain between 11 and 23% of the total effect of

SES on kindergartners' math achievement, when a composite of parent education, income, and occupation was used (Galindo & Sonnenschein, 2015). Notably, other studies have found no such effects (e.g., Manolitis et al., 2013; Skwarchuk et al., 2014), which suggests that the relation between parent math support and SES may not be straightforward, while it may also be due to differences in sample characteristics among studies. These conflicting findings may also be due to different conceptualizations of the math environment, and parents' activities in particular (Muñez & Bull, 2021).

US children from lower SES families have been found to perform worse in several domains related to math learning, such as numeracy (e.g., Starkey et al., 2004) and spatial reasoning (Starkey & Klein, 2008; Starkey et al., 2004; Verdine et al., 2014). Differences between SES groups, for example in block building, are already apparent by age 3 (Verdine et al., 2014) and persist despite children's participating in school readiness programs (e.g., Head Start) (Starkey et al., 2004). Disadvantages in math performance are prevalent already in kindergarten (e.g., Byrnes & Wasik, 2009; Jordan et al., 2006) and can perpetuate asymmetries in math development. Math advantage at kindergarten start is in fact an important factor in decreasing the SES-math achievement gap (Galindo & Sonnenschein, 2015). For example, Duncan and Magnuson (2011) reported marked SES disparities in math achievement in kindergarten in a longitudinal study with a US nationally representative sample. They compared the top and bottom 20% of the sample on SES and found that children differed in math achievement by 1.34 standard deviations on average.

Previous Reviews and Meta-analyses

One recent systematic review of 37 articles, carried out by Yildiz et al. (2020), examined the relation between spontaneous math support in the home and young children's math skills. This qualitative review revealed that advanced, but not basic numeracy interactions, were linked to children's math skills and that only mothers' reports (when compared to reports from both parents) of formal home numeracy activities were associated with math skills. Moreover, the authors concluded that the effect of formal home numeracy activities has been investigated more frequently than implicit/informal activities, that most studies have used questionnaires to assess home numeracy rather than observations, and that most studies focused on global math skills with comprehensive assessments, rather than specific types of math skill assessment. This literature review has, however, some limitations: (a) it focused on children of a broad age range (2-8 years of age), which can make it difficult to compare initial assessments and outcomes; (b) it was based on an initial pool of only 714 published articles identified through solely two databases; and (c) it failed to include either a quantitative analysis of the studies or an assessment of moderators that may explain variation in the results.

Importantly, a recent meta-analysis by Daucourt et al. (2021) examined the combined effect of several aspects of the HME, including math-related activities in the home but also parents' attitudes and expectations associated with children's math development. They examined families with children from 3 to 13 years and included seven HME domains: (1) direct activities; (2) indirect activities; (3) combination of direct and direct activities; (4) attitudes and beliefs; (5) math expectations; (6) spatial activities; and (7) math talk. The authors found a significant small correlation between the HME and children's math achievement ($r = .13$; SE = .02, $p < .001$). Our meta-analysis partially replicates the work by Daucourt and colleagues by focusing on *parent math support* specifically, as part of parent-child math-related activities in the home (e.g., Rittle-Jonhson, 2018; Zippert & Rittle-Johnson 2020), and by isolating the effects of parent math support during the *preschool years*. We aim to ascertain whether Daucourt et al.'s findings can be corroborated in a more circumscribed age range (3 to 5 years), examining exposure at a time when foundational math skills, important to school success, are rapidly developing. The preschool years are a time when parents are more likely to engage in teaching activities to their children (e.g., Daucourt et al. 2021). Once children enter first grade, parents often transfer the teaching responsibility to the school system. Hence, the selection of the 3- to 5-year-old age range for a meta-analysis has the potential to help understand whether parent math support is significantly related to preschool children's math skills and whether its effects remain over time.

The Present Study

The aim of this study was to conduct a meta-analysis on the literature examining concurrent and longitudinal relations between parent home-based math support in early childhood and math outcomes. Specifically, partially replicating and building on Daucourt et al.'s work (2021), this meta-analysis aimed to summarize the existing literature on the relation between *parent math support* between *ages 3 and 5* (i.e., before entering school) and children's math skills concurrently and longitudinally, as assessed by comprehensive measures of math performance or measures of more specific skills such as math problems, arithmetic, or numerical knowledge (e.g., Lehrl et al., 2020; Thippana et al., 2020; Zhang et al., 2020).

Even though general personal characteristics of the parents, and the general level of support they provide, are important contributors to children's math skills (Dearing et al., 2012), this study focused only on the specific early support parents provide relating to math skills. The role of more general cognitive support has been examined in previous studies, reporting a specific effect of support on math skills over and above that of general cognitive stimulation (see Ribeiro et al., 2020).

Specific research questions of this study included: (a) Is there a concurrent and longitudinal association between parent math support and children's math skills?; (b) Is this association moderated by type of Exposure (e.g., type of parent math support such as formal and informal activities) and type of Outcome (e.g., counting and numerical knowledge)?; (c) Are participants' characteristics (e.g., child age, child and parent gender) moderators of the association between parent math support and children's math abilities?; (d) Is parent education a moderator in the relation between parent math support and children's math skills?; (e) Are these relations consistent when potential sources of bias (i.e., geographical area and publication type) are accounted for?; (f) Do the selected studies fulfil appropriate methodological quality standards that lend confidence to our results?

Our study has taken into account potential sources of bias, such as geographical area and publication type, and the appraisal of methodological quality. The inclusion of geographical area as moderator, which is good practice in meta-analytic studies (Higgins et al., 2021), is considered especially relevant to our meta-analysis, since the range of our selected studies speaks to a diverse country profile. It could well be that language differences are reflected in some of our variables such as the type of parent math support within the home environment (e.g., Cankaya & LeFevre, 2016). Secondly, publication type, that is, if studies are published or unpublished, is also known to affect results. On one hand, it is more likely that published studies are those with larger and statistically significant findings since studies with null findings are harder to publish - an estimate of 21% - whereas 65% of studies with significant findings make it into a journal (Franco et al., 2014). On the other hand, meta-analyses that include unpublished studies are just as likely to show bias as those that do not include such studies, due to the selection bias involved in the search for unpublished literature (see Ferguson & Brannick, 2012). Finally, for the appraisal of the methodological quality of the selected studies, it is crucial to evaluate a series of aspects addressing potential risk of biases in each study's design, procedure, and result analyses. The quality of selected studies is an important aspect to take into account and methodological rigor should be examined to evaluate the consistency and strength of findings of selected studies. Overall, these aspects can be confounding variables that lead to misleading results, and, therefore, need to be examined.

Methods

Search Strategy

The design and reporting of this meta-analysis is in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Stroup et al., 2000). We developed a search strategy, which included combinations of search terms referring to the exposure variable *parent math support in the home* with search terms referring to *math outcomes.* These two main categories of search terms were combined in each database using the Boolean operator OR between search terms within each category, and the operator AND between the sets of search terms comprising the two categories. Thus, we combined terms related to parent math support (e.g., parent*, matern*, mother*, father*, home*, famil*) with those related to math outcomes (e.g., math*, counting*, numer*, and arithmet*).

We conducted the search in several databases, including the Cochrane Database of Systematic Reviews, ERIC, MEDLINE, PsycINFO, Web of Science, Scopus, and Google Scholar. Other search strategies included: (a) hand-search of relevant journals in the field (e.g., *Child Development, Developmental Psychology, Early Childhood Research Quarterly, Parenting: Science and Practice*); (b) citation searches by inspecting articles citing our selected studies; (c) inspecting reference lists of identified studies; and (d) ProQuest database in search for grey literature, more specifically theses and dissertations. Of the initial 2,163 abstracts screened, 135 studies were included and assessed for further full-text screening. From these, 90 were excluded because they did not fulfill the inclusion criteria (e.g., did not include preschool-aged children, did not include a math skills outcome) or they assessed math outcomes together with verbal and general aptitude dimensions. In 10 studies, the authors did not report the relevant coefficients and therefore were contacted by email. Three of these authors provided the relevant coefficients. This resulted in a total of 45 studies to be included in the analyses (see Figure 2).

Eligibility Criteria

Our search strategy included quantitative studies published in peer-reviewed journals and theses/dissertations published between 1985 and 2020 and written in the English language. The selection of the studies was conducted in two different steps: (i) screening by titles and abstracts, and (ii) full-text screening of all the articles that were found as potentially relevant for the review. We selected studies which (a) had a design that established an association between early parent math support in the home and children's math skills (concurrently or longitudinally), and (b) reported concurrent and/or longitudinal data on typically developing preschool children (from 3-5 years old or still not in formal schooling equivalent to first grade) and their mother and/or father. We had no exclusion criteria as to the length of the follow-up, which ranged from 6 months to 13 years.

As for our variables of interest, studies had to assess the association between parent math support and their children's math skills. On the one hand, eligible studies had to examine parent math support through the assessment of numeracy and/or spatial support related to materials and formal activities focused on math skills (e.g., counting, arithmetic operations, using geometrical shapes) or informal activities and materials (e.g., numeracy games, puzzle play, number talk). We included studies that assessed these activities either through parent self-report tools or observational scales aimed to measure parent math support referring to active play or parent-child interactions. We excluded studies based on a broad definition of parent involvement such as studies involving support outside the home context (e.g., parent activities organized at the school), and those focusing on the general home environment not specific to math (e.g., which reported on parents' education, SES, parents' attitudes or expectations toward math, general parenting styles), that did not include any reporting of formal or informal use of materials and activities involving math concepts. On the other hand, eligible studies had to include assessment of math skills concurrently or longitudinally and report primary outcome measures on math skills such as number sense, counting, calculation, math problems, etc., assessed with more general test batteries or more specific math competence scales. Examples of parent math support in the home and math-skills measures taken from our preliminary searches are reported in Table 1. Finally, we inspected studies for the same labs/research groups to make sure they referred to different samples and in one case (see footnote on Table 2) one study was eliminated because it referred to analyses of the same dataset.

Characteristics of Selected Studies

Selected studies (*n* = 45) included 22 cross-sectional studies, 16 longitudinal studies, and 7 studies that included both cross-sectional and longitudinal analyses. These articles were published between 2004 and 2020. Twenty of these studies assessed both formal and informal math support by the parents, whereas 17 studies included only informal components (e.g., playing math games), and 8 included only formal components (e.g., doing math exercises). Nineteen studies measured math outcomes with comprehensive assessments, that is, complete math test batteries (with two of these studies also including a measure of counting/number knowledge); 10 studies included measures of math problems (5 of which included also measures of arithmetic and 1 study included also arithmetic and counting/number knowledge); 6 studies included measures of arithmetic only; 4 studies included measures of arithmetic and counting/number knowledge measures; and 6 studies included measures of counting/number knowledge only (see Table 2).

Moderators

The following moderators were examined:

Type of Exposure and Outcome

Type of parent math support. Type of parent math support was coded as *formal* when it involved the frequency with which parents purposefully taught math activities to their children (e.g., teaching the child how to count), *informal* when it was part of play materials and activities (e.g., playing board games, cooking together or grocery shopping), or *mixed* when it assessed both.

Math skills. The type of math outcome was coded as *counting and numerical knowledge* (e.g., tasks assessing number naming, symbolic and non-symbolic number line estimation, number comparison, one-to-one correspondence, number order, numeral identification, ordinality, number combinations, and oral counting), *arithmetic skills* (e.g., additions, subtractions, written arithmetic, and arithmetic fluency tasks), *comprehensive assessment* (e.g., batteries of early math abilities), and *math problems* (e.g., Applied Problems subtest of the Revised Woodcock-Johnson Psycho-Educational Achievement Tests).

Matched specificity between parent math support and math skills. This variable was coded as *specific-specific,* when measures of both parent math support (exposure) and math skills (outcome) were assessments of isolated tasks/skills (e.g., just numeric reasoning), as *global-global* when both exposure and outcome were comprehensive assessments (e.g., complete test batteries), as *specific-global* when the exposure was specific and the outcome was global, and as *global-specific* when the exposure was global and the outcome specific.

Participants' Characteristics

Children's Age. The mean age (at T1) in months of the participants was coded and assessed as a continuous variable.

Children's Gender. The percentage of boys in each study was calculated and considered as a continuous variable.

Gender of the Parent Offering Support. The percentage of mothers who reported on math support in each study was calculated and considered as a continuous variable.

Parent Education

Parent education was coded as *low* (the majority of the sample did not have more than a high school diploma), *middle* (the majority of the sample attended some form of higher education but did not complete a bachelor's degree), and *upper-middle* (the majority of the sample completed a bachelors' degree). Parent education level was mostly reported in the articles jointly as "parent education" (70% of the articles), and as maternal education only (20%). Only two articles reported parent education level as the highest education of both parents. Finally, one article reported education for just the "primary caregiver" and another article reported "average education of both parents".

Coding and Calculation of Effect Sizes

We coded the studies that met the criteria for inclusion in this meta-analysis by extracting correlation coefficients (Pearson's *r*) for the associations between parent math support and children's math skills and recorded sample size (*N*). In other words, the articles needed to provide correlations or sufficient information to calculate an estimate of the effect size of parent math support and children's math skills. When multiple indicators of our variables of interest were reported (i.e., correlations derived from different math measures or measure subscales), these were also coded, but we did not include both correlations on total scores and subscales, to avoid redundancy in the data. Some studies reported both concurrent (e.g., correlations among parental math support and math skills at T1) and longitudinal data (e.g., correlations among parental math support at T1 and math skills at T2). In these cases, effects for each time point were considered separately. As for longitudinal studies with multiple time point assessments, we coded data on the longest follow-up only.

To conduct the analyses, we first converted the correlations to Fisher's Z to approximate a normal distribution of population effect sizes (Cohn & Becker, 2003). Note that in our dataset, a higher correlation indicated a stronger association between parent math support and children's math skills. Once the analysis was performed, we converted the results back to Pearson's *r* correlation coefficients to facilitate their interpretation.

Each effect size was coded on different rows of the dataset and studies' information included five main sections: (1) identification of study features (title, authors); (2) study design (e.g., cross-sectional vs. longitudinal); (3) participants' characteristics (children's age and gender, gender of the parent offering support, parent education); (4) math support variables (type of parent math support measure); (5) math outcomes (measures of math skills); (6) potential sources of bias (geographical area and type of publication); and (7) methodological quality of the selected studies.

To ensure the reliability of the coding procedures, two of the co-authors independently double-coded 26% of the articles (12 out of the 45) included in the meta-analysis. The quality of the coding was calculated on the effect sizes extracted for each study by using interrater reliability with Cohen's kappa (Cohen, 1960). A Cohen's kappa of .89 CI [.80, .97] was achieved, indicating high interrater reliability.

Statistical Analysis

We performed our analyses using "metafor" (Viechtbauer, 2010) and "clubSandwich" (Pustejovsky, 2017) in R statistical software package (R Core Team, 2020). We implemented Correlated and Hierarchical Effect models as this is recommended to estimate meta-analytic effects once accounting for complex structures of dependencies in the data (CHE; Pustejovsky & Tipton, 2021). CHE models derive from Robust Variance Estimation (RVE) models for handling effects and variance estimates related to within and between study dependencies (Fisher & Tipton, 2015; Tipton &

Pustejovsky, 2015; see also Pustejovsky & Tipton, 2021). RVE includes two different working models: the "correlational effects", which derive from the assumption that dependencies within studies result from sampling errors since multiple effect sizes are estimated on the same sample (i.e., a study includes several measures of the same construct or measures on different constructs), and "hierarchical effects", which are based on the assumption that dependencies in studies are nested because effect sizes derive from independent samples sharing some features (i.e., multiple research studies are conducted by the same lab or research group). These two models can be implemented simultaneously in the CHE models within a multilevel modelling framework. In our meta-analysis, we performed CHE models in two steps. Firstly, the structure of variances among effect sizes was computed in the "clubSandwich" package (Pustejovsky, 2017) by using a block-diagonal covariance matrix which assumed a correlation of $\rho = 0.5$ among effect sizes clustered in studies (Pustejovsky & Tipton, 2021). Then, the structure of variances was used in a two-level random effects model, with random intercepts for studies and individual effects, using maximum likelihood estimation (see Borenstein et al., 2011).

To assess variability in results and heterogeneity among studies, we used the following statistics: (i) Q-statistic to test the null-hypothesis that there is homogeneity in the underlying true effect size (either between or within studies); (ii) the I^2 to determine the percentage of variance attributable to true heterogeneity rather than sampling error; and (iii) the τ to examine the standard deviation of the true effect sizes between studies and between effects (Borenstein et al., 2011). In addition, we tested moderators as predictors in the meta-regression. Sometimes studies failed to report data on all moderators of interest, and we, therefore, conducted the moderator analysis only for moderators with at least $k = 5$ studies with complete information. A similar criterion was applied to categorical moderators, that is, the moderator analysis was performed only on levels of the moderator represented by at least $k = 5$ studies.

Publication bias. We assessed publication bias using various methods. First, we examined moderators related to potential sources of publication bias, including *geographical area* (i.e., where the study took place was coded into “Asia”, “Europe”, “US”, and “Others”) and *publication type* (i.e., papers published in peer-review journals were coded as “published” and theses as “unpublished”).

Secondly, we assessed contour-enhanced funnel plots in which the reference line was 0. The contours referred to different levels of two-tailed *p*-values, and each effect size estimate was plotted as a function of the standard error of those estimates. When publication bias related to underreporting of non-significant findings is present, the plot is asymmetrical with missing effect size estimates in the rightward area due to underreporting of non-significant results in studies with small samples. As relying just on visual inspection of the funnel plot is unreliable, we quantitatively assessed its asymmetry using the Egger’s tests (Egger et al., 1997). The Egger’s test consists of a meta-regression in which the standard errors of the effect size estimates are used as predictors. When the Egger’s test is significant, this points out to an asymmetry in the funnel plots. In this case, it is possible to perform the PET-PEESE analysis (Carter et al., 2019). The PET-PEESE method consists of two conditional meta-regressions in which the standard errors (first step) and variances of the effect size estimates (second step) are entered (once at a time) as a predictor of the effect size estimates (Egger et al., 1997; Stanley, 2008; Stanley & Doucouliagos, 2014). While the Egger’s test examines whether the slope is statistically significant, the PET-PEESE method examines the intercepts that are interpreted as the unbiased estimates once accounting for small-study effects. According to Stanley’s (2017), when the PET estimate is statistically non-significant, the PET estimate is taken as the PET-PEESE estimate. However, when the PET estimate is statistically significant, the PEESE estimate is used as the PET-PEESE estimate (i.e., PEESE is considered a better estimate when the PET indicates a non-zero true effect size).

Assessment of study quality. We used the Joanna Briggs Institute (JBI) critical appraisal checklist for cross-sectional studies to evaluate study quality (Moola et al., 2020). The JBI aims to assess the methodological study quality and possible sources of bias. The protocol checklist evaluates the following areas: (i) inclusion criteria and sample description; (ii) validity and reliability of the exposure measures; (iii) identification and strategies to account for confounding factors; (iv) validity and reliability of outcome measures; and (v) suitability of the statistical analyses. We adapted the checklist identifying seven main criteria related to potential biases: (1) inclusion criteria for selecting participants (age, gender, and parent education); (2) details of participants and study context (e.g., inclusion criteria); (3) quality of the instrument used to assess parent math support (e.g., reliability); (4) extent to which confounding factors were identified (e.g., child language skills); (5) extent to which these confounding factors were controlled for in the analyses; (6) quality of the instrument used to assess math skills (e.g., standardization); and (7) quality of the statistical analyses. This tool has been considered to have adequate face validity and it has been recommended for the evaluation of cross-sectional studies (Ma et al., 2020). Given the lack of any current tool for study appraisal of studies that do not include a comparison group (not-experimental and not randomized), it was the view of the JBI research group that this tool would be made available to help researchers conduct their systematic reviews (Munn et al., 2020; Ma et al., 2020).

All included studies were assessed by two independent coders and disagreements were solved by consensus. Each study was rated on these seven items as a “1” (Yes, fulfills the criterion) or “0” (No, does not fulfill the criterion). We created a general appraisal for each study by computing the proportion of “yes” responses on the possible maximum “yes” codings. In accordance with the JBI Reviewers’ Manual (Joanna Briggs Institute, 2016), the following cut-offs were agreed prior to rating each study: high-bias = lower than 49%; moderate-bias = from 50 to 69%; low-bias = higher than 70%.

Results

We first assessed the concurrent associations between parent math support and math skills, and the effect of moderators in that relation. Then, we evaluated the longitudinal association between parent math support and later math skills. Finally, we examined results from the publication bias analysis and assessment of study quality for the concurrent and longitudinal studies.

Primary Analysis of the Concurrent Association Between Parent Math Support and Children's Math Skills

The concurrent association between parent math support and children's math skills was investigated in 29 studies, including 137 effect sizes. These studies were published from 2004 to 2020 and included 3882 children with a mean age of 4.99 years (*M* = 59.83, range from 38 to 82 months, 49.50% boys) and their parents (82.98% mothers). The overall meta-analytic estimate showed a positive and statistically significant, albeit small, association between parent math support and children's math skills, Pearson's $r = .13$, 95% CI [.09, .17], and the overall heterogeneity was moderate ($I^2 = 68\%$). Heterogeneity in the estimated true effect size across studies (τstudy = .04) was small and heterogeneity between effect sizes ($\omega = .12$) was large. As there were too many single effect sizes (k = 137), the forest plot refers to the single effect sizes (transformed to Pearson's *r*) aggregated by study (see Figure 3).

Moderator Analysis on the Concurrent Association Between Parent Math Support and Children's Math Skills

First, we examined moderators related to the type of exposure and outcome, such as the type of parent math support and math skills, and the matched specificity between exposure and outcome. For the type of parent math support, we had an adequate number of studies for the analysis for *formal* (13 studies), *informal* (14 studies), and *mixed* activities (9 studies). However, there was no evidence of a difference between the three categories, Q(2) = .27, *p* = .873. The Pearson's *r* was .13 [.08, .19] for *formal*, .12 [.06, .17] for *informal*, and .12 [.06, .19] for *mixed* activities.

As for math outcomes, most studies used *comprehensive assessment* batteries (14 studies), *counting & numerical knowledge* (11 studies) or *arithmetical skills* (8 studies), with only a few examining *math problems* (3 studies). When comprehensive assessment batteries, counting and numerical knowledge and arithmetical skills were compared, the moderator analysis was non-significant, Q(2) = 1.37, *p* = .503, and the Pearson's *r comprehensive assessment*, *r* = .15 [.08, .22], *counting and numerical knowledge*, *r* = .11 [.06, .16], and *arithmetical skills*, *r* = .09 [.02, .17] were similar. In addition, we examined the moderator effect of the *matched specificity between exposure and outcome*. We had a similar number of studies examining *global exposure with specific outcome* (10 studies), *global exposure with global outcome* (8 studies), *specific exposure with global outcome* (7 studies), and *specific exposure with specific outcome* (7 studies). The moderator analysis was only marginally significant Q(3) = 7.81, *p* = .05, most certainly due to lack of power. The Pearson's *r* was *r* = .14 [.08, .19] for *global exposure with specific outcome*, *r* = .24 [.14, .34] for *global exposure with global outcome*, *r* = .09 [.01, .17] for *specific exposure with global outcome*, and *r* = .08 [.14, .15] for *specific exposure with specific outcome*. As the magnitude of the effect sizes was larger for the two categories involving *global exposure* (although this was especially true for the category *global exposure with global* outcome), we conducted an additional analysis enabling us to compare just the *specificity of the exposure*, for slightly increased power. There were a few more studies using *global* as opposed to *specific* measures of parent math support (17 vs 13 studies, respectively). The moderator analysis was statistically significant Q(1) = 4.75, *p* = .03, with the Pearson's *r* for *global* exposure, *r* = .17 [.12, .23], showing higher correlations than for *specific* exposure, *r* = .08 [.02, .14]. We could not examine observational data vs. self-report, nor quality vs. quantity of math exposure as moderators, because not enough selected studies were observational studies (and very few reported on the quality of parental math support).

Second, we assessed moderators related to participants' characteristics - children's age and gender and gender of the parent offering support – as well as parent education. All 29 studies reported information on children's age and gender, but neither emerged as a statistically significant moderator with Q(1) = .02, *p* = .901, B = .0002 and Q(1) = 1.12, *p* = .289, B = -.39, respectively. Twenty-three studies included data on gender of the parent offering support, but this variable did not emerge as a statistically significant moderator, Q(1) = 1.04, *p* = .309, B = -.05. As for parent education, we had a sufficient number of studies for middle (10 studies) and upper-middle (13 studies) education levels, but not for low education level (3 studies). When middle and upper-middle levels were compared, no statistically significant differences between these two levels of the moderator emerged, Q(1) = .15, *p* = .697. The Pearson's *r* in these two categories corresponded to .14 [.06, .22] for middle and .12 [.05, .19] for upper-middle education level.

Primary Analysis of the Longitudinal Association Between Parent Math Support and Children's Math Skills

As for the longitudinal association between parent math support and later math skills, 23 studies with 64 effect sizes were found. Altogether, studies were published from 2010 to 2020 and included 11420 children with a mean age of 7.13 years (*M* = 85.54 months, range from 22 to 180 months, 53.17% boys) and their parents (87.89% mothers). Longitudinal assessments were conducted with a mean follow-up of 35.45 months ranging from 6 to 162 months.

The overall meta-analytic estimate between early parent math support and later math skills was positive and statistically significant, albeit small, Pearson's *r* = .15, 95% CI [.09, .20], and the overall heterogeneity was high (I^2 = 87%). Heterogeneity in the estimated true effect size across studies (τstudy

= .10) and heterogeneity between effect sizes (ω = .11) were large. We aggregated the single effect sizes (transformed to Pearson's *r*) by study and reported them in a forest plot to provide the information on each single study (see Figure 4).

Publication Bias Analyses

First, we examined possible sources of bias by evaluating geographical area and publication type as moderators of the effect size estimates in the concurrent and longitudinal studies. Most of the cross-sectional studies were conducted in the US (15 studies), some in Europe (6 studies) and Asia (6 studies), and only a few in other countries (4 studies). The moderator analysis did not indicate a statistically significant difference between the three levels of the moderator (i.e., the US, Europe, and Asia), Q(2) = 2.24, *p* = .326. Pearson's *r* corresponded to .16 [.09, .23] for studies conducted in the US, .19 [.08, .29] for studies located in Europe, and .10 [.02, .17] for studies identified in Asia. As for longitudinal studies, most research was carried out in the US (10 studies) and Europe (9 studies), and only a minority in Asia (1 study) or other countries (4 studies). When the US and Europe were considered, the moderator did not emerge as a significant, Q(1) = 2.54, *p* = .111. The Pearson's *r* was .21 [.10, .30] for the US and .09 [.00, .19] for Europe. As for publication type, there were no unpublished studies either for the concurrent or the longitudinal studies to perform the analysis.

Second, we examined the contour-enhanced funnel plots for the concurrent and longitudinal studies, which are reported in Figure 5 and Figure 6, respectively. The Egger's test was non-significant (B = .13, *SE* = .55, *Z* = 0.23, *p* = .816) for the concurrent studies, indicating that the funnel plot was reasonably symmetrical. As the Egger's test was non-significant, we did not perform the PET-PEESE analysis for the concurrent studies. Then, we conducted the Egger's test for the longitudinal studies. Results indicated a statistically significant effect (B = 1.79, *SE* = .71, *Z* = 2.53, *p* = .011), suggesting that the funnel plot was asymmetrical and there was bias related to small-study effects. Thus, we conducted the PET-PEESE analysis. The PET showed that the bias-corrected effect was positive but no longer significant, $r = .01$ [-.10, .13], $p = .841$. As the PET was not significant, the PEESE was not performed.

Assessment of Study Quality

The results of the methodological quality assessment showed that, of the 45 articles considered, 27 (60%) were judged to have "low" risk of bias, 14 (31%) had a "moderate" risk of bias (31%), and 4 (9%) had a "high" risk of bias. We did not find any significant differences in the overall ratings between concurrent and longitudinal studies when performing non-parametric mean comparisons of scores obtained in the two types of studies (U = 196.5, $p = .190$). In terms of the seven criteria evaluated, four of them (criteria 1, 2, 6, and 7) obtained 80% or more of 1s ("Yes" fulfills the criterion), whereas three of them (criteria 3, 4 and 5) had lower rates of 1s (56, 44, and 31% respectively). Note that criterion 3 refers to the quality of the exposure measure used to assess parent math support. In fact, many of the articles included *ad-hoc* measures developed for the specific studies or used adapted versions of standardized parent math support measures, not always validated, or not including reliability data on the study sample. Moreover, criteria 4 and 5 refer to the ability to identify and account for confounding factors like child language or parent IQ. In fact, only a small percentage of selected studies reported adequate data on confounding factors such as child language measures. There were significant differences for criteria 4 and 5 between cross-sectional and longitudinal studies, with the latter showing higher quality ratings than the former (criterion 4, U = 145.5, $p = .005$; criterion 5, 165.5, $p =.014$). No significant differences were found for the remaining criteria between cross-sectional and longitudinal studies.

Discussion

This study focused on examining the meta-analytic association between parent math support in early childhood and math skills of children from diverse nationalities in Europe, America, and Asia. We investigated the moderating role of i) type of parent math support; ii) type of math outcome; iii) matched specificity between exposure and outcome; iv) child age and gender; v) gender of the parent offering support; and vi) parent education. Our findings supported a small but significant positive association between parent math support and children's math skills both concurrently, r = .13 95% CI [0.09, 0.17], and longitudinally, r = .15 95% CI [0.09, 0.20], indicating that, on average, higher parent math support is associated with better maths skills in their children. Concurrent and longitudinal effects were similar in terms of their magnitude, although caution is need in establishing a parallel because the estimate for the longitudinal studies was affected by studies with small samples and it is therefore not robust. Our results are consistent with the findings of the recent meta-analytic study conducted by Daucourt et al. (2021), confirming and isolating the effect of *parental math support* in the *preschool period*. They also found small and positive associations between HME and child math outcomes, although their exposure measure also included parents' beliefs and attitudes toward math and not only parent math activities in the home, like our study did.

We found a moderate heterogeneity for the concurrent and longitudinal studies, with Pearson's r correlations aggregated by study varying between -.47 and .57 for the former and between -.10 and .47 for the latter. However, none of the assessed moderators accounted for variation in the results of the concurrent studies. It is worth noting that there were few studies on *low-education* and including measures of *math problems* and, consequently, we had limited information on these variables to compare categories within each moderator and fully assess the role of parent education and type of math skills in the moderator analyses. It was also not possible to test the joint role of our moderators in the same meta-regression as only 17 concurrent studies reported complete information on all the variables of interest. Overall, these results may indicate that we had limited power to examine the role of our moderators in explaining variation in the results. The exception was the role of the variable *specificity of the exposure*. A significantly higher effect was found for studies including a *global* parent math support (exposure) measure when compared to studies using a *specific* measure. This could point to the importance of using varied tasks and activities when stimulating children's math abilities at home.

Our meta-analysis focused on children between 3-5 years of age at exposure and we could not find any age effects within this narrow age range. Daucourt et al. (2021) found a moderator effect of grade, with younger children at exposure showing the strongest effects. However, our results cannot be compared directly with those from Daucourt et al. since they considered children's grade. These authors also found other moderator effects such as the type of math outcome, with numerical reasoning being the only outcome associated with every aspect of their exposure variable. Notably, they also found associations between parent activity measures (similar to our parent math support variable) and numerical reasoning, which included skills like counting and number recognition (and, therefore, similar to our *Counting/Number Knowledge* subdomain).

As for potential sources of bias, geographical area did not explain variation in the results in the concurrent or longitudinal studies. In addition, no unpublished studies were retrieved to analyse publication type. When it came to publication bias analysis, results showed small-study effects for longitudinal but not for concurrent studies. As for the longitudinal studies, the PET analysis indicated that there was publication bias and that the bias-corrected effect may be null. Notably, PET-PEESE performs poorly in meta-analysis with few studies, studies with small samples, or high heterogeneity between studies (Stanley, 2017). However, initial simulation results indicated that the PET-PEESE estimator's performance is promising (Stanley & Doucouliagos, 2014), and additional evidence shows that, under the same conditions, the PET-PEESE performs better than the conventional meta-analysis approaches (Stanley, 2017).

Unique advantages to our meta-analysis include: (i) precise focus (i.e., associations between *early parent math support* and children's math skills); ii) focused age range (i.e., parent math support occurring within a narrow age range before school start, thus isolating the effect of *parent math support before formal schooling*, a time when parent influences may be particularly relevant); (iii) inclusion of both concurrent and longitudinal studies (with varied and long follow-ups specified for each study); (iv) use of advanced meta-analytic methods to handle dependencies in the data; and (v) examination of the methodological quality of selected studies. In fact, our study had the advantage of including a quantitative analysis of the association between parent math support and children's math skills focusing on a targeted age group of children upon exposure (3-5 years). This makes it easier to compare initial assessments and outcomes and capture a more uniform set of measures of both parent math support and math skills. Secondly, one other strength of our meta-analysis is that the selected studies included longitudinal follow-up data, which enabled us to establish long-term associations between parent math support and children's math skills within varied and long follow-up periods from 6 months to 13.5 years (average 2.4 years). Thirdly, we used state-of-the-art meta-analytic techniques, such CHE models derived from Robust Variance Estimation (RVE), which are privileged models for handling effects and variance estimates related to within and between study dependencies. The sophistication of the statistical methods employed helped attain more reliable findings and calculate more precise estimates. Finally, we can assume there was a low risk of bias due to the quality of selected studies. Our standardized appraisal of each study revealed generally good methodological quality based on all parameters, with the exception of the parameter involving the validity of the measure of parent math support (exposure) and the parameters involving confounding factors. In fact, the lack of standardized measures to assess parent math support in the home was reflected in a majority of *ad-hoc* measures and translated measures, which were sometimes not validated for a given dataset. This seems to be a shortcoming in this field, suggesting the need for reliable and valid measures to assess parent math support in the home. Also, most studies in this field fail to include and control for important confounding factors such as child language skills or IQ.

Limitations and suggestions for future studies

It is important to note that our effects were small in magnitude and very similar to the correlations found in the previous meta-analysis by Daucourt and colleagues, which albeit having a much wider focus, is the closest study to ours, serving as a benchmark to interpret our effect sizes (Funder & Ozer, 2020). Moreover, we found heterogeneity of effect sizes across studies, which we were not able to account for with our chosen moderators. It is possible that some of that heterogeneity is due to methodological aspects, such as the quality of the parent math support measures, or to the fact that we did not have enough studies and therefore lacked enough power to detect such sources of variability, specifically for some of the moderators. In fact, the small sample sizes for subgroup analyses did not enable us to draw any conclusions regarding the robustness of our moderator null findings, namely those related to low parent education, fathers as those providing math support, and *math problems* as outcomes.

Another important aspect is that we initially aimed to include language skills as a moderator. Early language skills (e.g., general vocabulary, number words) have been found to mediate the relation between parent education and math ability (e.g., Slusser et al., 2018), although more complex language and mathematics skills are associated with stronger relations between language and mathematics (e.g., Peng et al., 2020). However, in our dataset, only 16 of the reviewed studies reported data on language measures (mainly the Peabody Vocabulary Test) and these were raw data rather than standardized data, which carried additional problems since the selected studies referred to samples from different countries/languages. We tried our best to retrieve data from the authors but, in the end, we were left with insufficient data available, which did not enable us to further analyze the moderator role of language skills in the relation between parent math support and math ability. Further studies should include measures on children verbal and general ability and also, ideally, on parents' abilities (IQ, verbal ability and math skills) in order to enable research designs that isolate the individual contribution of parent math support to children's math outcomes.

Another limitation of our study is the inclusion of solely published articles. Study selection was based on a large initial pool of published data, and we devoted great effort to the search for grey literature carefully reviewing materials registered in the ProQuest Database for Theses and Dissertations from 1985 to 2020. However, we found no unpublished studies that fulfilled our criteria. The works scanned were often focused on math intervention studies carried out in the educational context. In fact, it appears that placing the focus on parent math support in connection to children's math skills is a somewhat recent endeavor. All eligible articles were published after 2004, although our searches started with studies dating back to 1985. Therefore, our selection includes studies published over a short period span of only 16 years and that can explain the non-existence of grey literature in the ProQuest Database that fulfilled our inclusion criteria. We have also contacted a research association expert in the field in an attempt to reach grey literature in the broader research community, but we did not receive any feedback to our request within our established timeframe.

Given the methodological salience of observational studies in the field of developmental psychology (Ostov & Hart, 2013; NICHD, 1999), notably those involving quality ratings of parent-child interactions, we point as a further limitation that, due to very few observational studies included in this meta-analysis, we could not disentangle the effect of parent math support assessed with this kind of methodology. Our findings are therefore largely based on self-report questionnaires and frequency counts of instances/activities involving parent math support and conclusions cannot be drawn to either observational studies or those involving quality ratings of parent math support.

Another limitation of this study deserves acknowledgment. There is considerable variation in the literature with regard to terminology relating to parent/caregiver support of math skills in the home. Terms like *parent involvement*, *parent support*, *parent engagement* have been used more or less interchangeably, which posed challenges in guaranteeing full coverage of the relevant studies. However, we are confident that our study selection depicts the current state of the art with regards to the literature on the association between parent math support and math skills. Finally, our study included only typically developing children and so our conclusions can only be applied to normative samples and no assumptions can be drawn to specific populations such as children at-risk for developmental disabilities, language impairments, and so on.

Finally, another limitation of our study was related to parental education and its relation to math support in the home. As we have seen, in most studies, the caregivers reporting on math support were mothers but most articles (70%) offered information on educational level for both parents, without informing how the index was calculated. Hence, without alignment between the parent whose education is being reported and the parent who reports math activities in the home, it is not possible to make sense of the contribution of parent education to math support and their interplay as relevant for child math skills.

Conclusions and Implications

This meta-analytic study yielded important conclusions with respect to the association between parent math support and children's math skills, an important finding that can have implications for research and educational practices. Our study supports the relevance of early math interventions supporting parents' provision of math related activities and materials in the family *microsystem* over the preschool period, which may be particularly beneficial for children at risk for poor math skills (Mix & Cheng, 2012).

Dearing and associates (2012) found that the general quality of the home learning environment and specific math activities in the home both mediated the relation between family socioeconomic factors and math skills. Ultimately, such results can support the long-term goal to provide math training to parents so they can compensate for the effects of deprived environments due to socioeconomic factors. Further research is warranted to be able to offer evidence-based recommendations for the particular importance of parent math support for low-income families, since our study did not include enough data on such families. In particular, understanding family stress and parental investment pathways, often identified as mediating mechanisms between family income and child outcomes (see e.g., Duncan et al., 2015), would be an important future direction. Furthermore, studies should also strive to clarify the confounding issue of using different SES measures (e.g., Ensminger et al., 2003), for example, disentagling the effect of SES measured with a single vs. multiple indicators on math outcomes.

Building on a (bio)ecological approach, we confirmed our hypothesis that parent math support predicts better math skills both concurrently and longitudinally. We were not able to draw conclusions for the moderator effects of type of parent math support, type of math skills, child age, child/parent gender and parent education, due to both non-significant findings and small sample sizes in a given category (e.g., not enough individuals from low parent education backgrounds). Future studies are warranted to investigate aspects of the model not contemplated by our design such as issues related to differences in parent math support across families, school systems, and communities. This meta-analysis pointed to the importance of considering the association between parent math support in the home and children’s math skills. This finding can be a starting point to future studies that can identify strategies that optimize parent math support in the home, prior to school entry, to foster early numerical skills and later math development.

References

*References marked with an asterisk indicate studies included in this meta-analysis.

Anders, Y., Rossbach, H. G., Weinert, S., Ebert, S., Kuger, S., Lehrl, S., & von Maurice, J. (2012). Home and preschool learning environments and their relations to the development of early numeracy skills. *Early Childhood Research Quarterly*, *27*, 231-244. https://doi.org/10.1016/j.ecresq.2011.08.003

Ashiabi, G. S., & O'Neal, K. K. (2015). Child Social Development in Context: An Examination of Some Propositions in Bronfenbrenner's Bioecological Theory. *SAGE Open*, *5*(2). https://doi.org/10.1177/2158244015590840

Aunola, K., & Räsänen, P. (2007). *The 3-Minute Basic Arithmetic Test.* Unpublished test material, Department of Psychology, University of Jyväskylä, Finland.

Aunio, P., & Niemivirta, M. (2010). Predicting children's mathematical performance in grade one by early numeracy. *Learning and Individual Differences*, *20*(5), 427-435. https://doi.org/10.1016/j.lindif.2010.06.003

*Benigno, J. P., & Ellis, S. (2004). Two is greater than three: Effects of older siblings on parental support of preschoolers' counting in middle-income families. *Early Childhood Research Quarterly*, *19*(1), 4-20. https://doi.org/10.1016/j.ecresq.2004.01.006

Berkowitz, T., Schaeffer, M. W., Maloney, E. A., Peterson, L., Gregor, C., Levine, S. C., & Beilock, S. L. (2015). Math at home adds up to achievement in school. *Science, 350,* 196–198. https://doi.org/10.1126/science.aac7427

Blevins-Knabe, B., Austin, A. B., Musun, L., Eddy, A., & Jones, R. M. (2000). Family home care providers' and parents' beliefs and practices concerning mathematics with young children. *Early Child Development and Care*, *165*(1), 41-58. https://doi.org/10.1080/0300443001650104

Blevins-Knabe B. (2016). Early mathematical development: How the Home Environment Matters. In: Blevins-Knabe B., Austin A. (eds) *Early Childhood Mathematics Skill Development in the Home Environment*. Springer, Cham. https://doi.org/10.1007/978-3-319-43974-7_2

Blevins-Knabe, B., & Musun-Miller, L. (1996). Number use at home by children and their parents and its relationship to early mathematical performance. *Early Development and Parenting: An International Journal of Research and Practice*, *5*, 35-45. https://doi.org/10.1002/(SICI)1099-0917(199603)5:1<35::AID-EDP113>3.0.CO;2-0

Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2011). *Introduction to meta-analysis*: John Wiley & Sons.

Bracken, B.A. (2006). *Bracken Basic Concept Scale-Third Edition: Receptive.* San Antonio, TX: The Psychological Corporation.

Burchinal, M., Nelson, L., Carlson, M., & Brooks-Gunn, J. (2008). Neighborhood characteristics, and child care type and quality. *Early Education and Development*, *19*, 702-725. https://doi.org/10.1080/10409280802375273

Byrnes, J. P., & Wasik, B. A. (2009). Factors predictive of mathematics achievement in kindergarten, first and third grades: An opportunity–propensity analysis. *Contemporary Educational Psychology*, *34*(2), 167-183. https://doi.org/10.1016/j.cedpsych.2009.01.002

Cankaya O., LeFevre JA. (2016) The Home Numeracy Environment: What Do Cross-Cultural Comparisons Tell Us About How to Scaffold Young Children's Mathematical Skills?. In: Blevins-Knabe B., Austin A. (eds) *Early Childhood Mathematics Skill Development in the Home Environment.* Springer, Cham. https://doi.org/10.1007/978-3-319-43974-7_6

Cannon, J. & Ginsburg, H.P. (2008) “Doing the math”: Maternal beliefs about early mathematics versus language learning. *Early Education and Development, 19*, 238-260. https://www.tandfonline.com/action/showCitFormats?doi=10.1080%2F10409280801963913

Carter, E. C., Schönbrodt, F. D., Gervais, W. M., & Hilgard, J. (2019). Correcting for bias in psychology: A comparison of meta-analytic methods. *Advances in Methods and Practices in Psychological Science*, *2*(2), 115-144. https://doi.org/10.1177/2515245919847196

*Casey, B. M., Lombardi, C. M., Thomson, D., Nguyen, H. N., Paz, M., Theriault, C. A., & Dearing, E. (2018). Maternal support of children's early numerical concept learning predicts preschool and first-grade math achievement. *Child Development*, *89*(1), 156-173. https://doi.org/10.1111/cdev.12676

Chang, A., Sandhofer, C. M., & Brown, C. S. (2011). Gender biases in early number exposure to preschool-aged children. *Journal of Language and Social Psychology*, *30*(4), 440-450. https://doi.org/10.1177/0261927X11416207

*Cheung, S. K., Yang, X., Dulay, K. M., & McBride, C. (2018). Family and individual variables associated with young Filipino children's numeracy interest and competence. *British Journal of Developmental Psychology*, *36*(2), 334-353. https://doi.org/10.1111/bjdp.12222

*Cheung, S. K., Dulay, K. M., & McBride, C. (2020). Parents’ characteristics, the home environment, and children’s numeracy skills: How are they related in low-to middle-income families in the Philippines?. *Journal of Experimental Child Psychology, 192*, 1-19. https://doi.org/10.1016/j.jecp.2019.104780

Clements, D. H., & Sarama, J. (2009). *Learning and Teaching Early Math: The Learning Trajectories Approach*. Routledge.

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement, 20*(1), 37–46. https://doi.org/10.1177/001316446002000104

Cohn, L. D., & Becker, B. J. (2003). How meta-analysis increases statistical power. *Psychological Methods, 8*(3), 243–253. https://doi.org/10.1037/1082-989X.8.3.243

Crosnoe, R., Leventhal, T., Wirth, R. J., Pierce, K. M., Pianta, R. C., & NICHD Early Child Care Research Network. (2010). Family socioeconomic status and consistent environmental support in early childhood. *Child Development, 81*, 972-987. https://doi.org/10.1111/j.1467-8624.2010.01446.x

Daucourt, M. C., Napoli, A. R., Quinn, J. M., Wood, S. G., & Hart, S. A. (2021). The home math environment and math achievement: A meta-analysis. *Psychological Bulletin, 147*(6), 565. https://doi.org/10.1037/bul0000330

*De Keyser, L., Bakker, M., Rathé, S., Wijns, N., Torbeyns, J., Verschaffel, L., & De Smedt, B. (2020). No association between the home math environment and numerical and patterning skills in a large and diverse sample of 5-to 6-year-olds. *Frontiers in Psychology, 11*, 1-13. https://doi.org/10.3389/fpsyg.2020.547626

Dearing, E., Casey, B. M., Ganley, C. M., Tillinger, M., Laski, E., & Monticello, C. (2012). Young girls' arithmetic and spatial skills: The distal and proximal roles of family socioeconomics and home learning experiences. *Early Childhood Research Quarterly, 27*, 458-470. https://doi.org/10.1016/j.ecresq.2012.01.002

*Del Río, M. F., Susperreguy, M. I., Strasser, K., & Salinas, V. (2017). Distinct influences of mothers and fathers on kindergartners' numeracy performance: The role of math anxiety, home numeracy practices, and numeracy expectations. *Early Education and Development*, *28*(8), 939-955. https://doi.org/10.1080/10409289.2017.1331662

*DeFlorio, L., & Beliakoff, A. (2015). Socioeconomic status and preschoolers' mathematical knowledge: The contribution of home activities and parent beliefs. *Early Education and Development*, *26*, 319-341. https://doi.org/10.1080/10409289.2015.968239

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P.,et al. (2007). School readiness and later achievement. *Developmental Psychology, 43*, 1428–1446. https://doi.org/10.1037/0012-1649.43.6.1428

Duncan, G.J. & Magnuson, K. (2011). The Nature and Impact of Early Achievement Skills, Attention Skills, and Behavior Problems, in Greg J. Duncan & Richard J. Murnane (Eds.), *Whither Opportunity: Rising Inequality, Schools, and Children's Life Chances* (pp 47-69). Russell.

Duncan, G. J., Magnuson, K., & Votruba-Drzal, E. (2015). Children and Socioeconomic Status. In *Handbook of Child Psychology and Developmental Science*: John Wiley & Sons, Inc.

Dunst, C. J., Hamby, D. W., Wilkie, H., & Dunst, K. S. (2017). Meta-analysis of the relationship between home and family experiences and young children's early numeracy learning. *Engaging Families as Children's First Mathematics Educators: International Perspectives*, 105-125

Egger, M., Smith, G. D., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *BMJ, 315*(7109), 629-634. https://doi.org/10.1136/bmj.315.7109.629

Elliott, L., & Bachman, H. J. (2018a). SES disparities in early math abilities: The contributions of parents' math cognitions, practices to support math, and math talk. *Developmental Review*, *49*, 1-15. https://doi.org/10.1016/j.dr.2018.08.001

Elliott, L., & Bachman, H. J. (2018b). How do parents foster young children's math skills? *Child Development Perspectives*, *12*, 16-21. https://doi.org/10.1111/cdep.12249

*Elliott, L., Braham, E. J., & Libertus, M. E. (2017). Understanding sources of individual variability in parents' number talk with young children. *Journal of Experimental Child Psychology*, *159*, 1-15. https://doi.org/10.1016/j.jecp.2017.01.011

Ensminger, M. E., Fothergill, K. E., Bornstein, M. H., & Bradley, R. H. (2003). A decade of measuring SES: What it tells us and where to go from here. *Socioeconomic status, parenting, and child development*, *13*, 27.

*Evans, D., & Field, A. P. (2020). Predictors of mathematical attainment trajectories across the primary-to-secondary education transition: Parental factors and the home environment. *Royal Society Open Science, 7*(7), 1-20. http://dx.doi.org/10.1098/rsos.200422

Ferguson, C. J., & Brannick, M. T. (2012). Publication bias in psychological science: Prevalence, methods for identifying and controlling, and implications for the use of meta-analyses. *Psychological Methods, 17*(1), 120–128. https://doi.org/10.1037/a0024445

Fisher, Z., & Tipton, E. (2015). robumeta: An R-package for robust variance estimation in meta-analysis. *arXiv preprint arXiv:1503.02220*.

Franco, A., Malhotra, N., & Simonovits, G. (2014). Publication bias in the social sciences: Unlocking the file drawer. *Science*, *345*(6203), 1502-1505. https://www.science.org/doi/abs/10.1126/science.1255484

Funder, D. C., & Ozer, D. J. (2020). "Evaluating effect size in psychological research: Sense and nonsense": Corrigendum. *Advances in Methods and Practices in Psychological Science, 3*(4), 509. https://doi.org/10.1177/2515245920979282Galindo, C., & Sonnenschein, S. (2015). Decreasing the SES math achievement gap: Initial math proficiency and home learning environments. *Contemporary Educational Psychology*, *43*, 25-38. https://doi.org/10.1016/j.cedpsych.2015.08.003

Gibbs, B. G. (2010). Reversing fortunes or content change? Gender gaps in math-related skill throughout childhood. *Social Science Research*, *39*(4), 540-569. https://doi.org/10.1016/j.ssresearch.2010.02.005

Ginsburg, H., & Baroody, A. (2003). TEMA-3 examiners manual. *Austin, TX: Pro-Ed*.

Ginsburg, H. P., Lee, J. S., & Boyd, J. S. (2008). Mathematics education for young children: What it is and how to promote it. *Social Policy Report*, *22*(1), 1-24. https://srcd.onlinelibrary.wiley.com/doi/pdf/10.1002/j.2379-3988.2008.tb00054.x

Gustafsson, J. E., Hansen, K. Y., & Rosén, M. (2011). Effects of home background on student achievement in reading, mathematics, and science at the fourth grade. *TIMSS and PIRLS*, 181-287.

Halpern, D. F., Benbow, C. P., Geary, D. C., Gur, R. C., Hyde, J. S., & Gernsbacher, M. A. (2007). The science of gender differences in science and mathematics. Psychological Science in the Public Interest, 8, 1–51. https://doi. org/10.1111/j.1529-1006.2007.00032.x

Heckman, J. J. (2006). Skill formation and the economics of investing in disadvantaged children. *Science, 312*, 1900-1902. https://doi.org/10.1126/science.1128898

Higgins, J. P. T., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M. J., Welch, V. A. (editors). *Cochrane Handbook for Systematic Reviews of Interventions* version 6.2 (updated February 2021). Cochrane, 2021. Available from *www.training.cochrane.org/handbook*

Hojnoski, R. L., & Floyd, R. G. (2013). Individual growth and development indicators of early numeracy (IGDIs-EN). Minneapolis, MN: Early Learning Labs.

*Huang, Q., Zhang, X., Liu, Y., Yang, W., & Song, Z. (2017). The contribution of parent–child numeracy activities to young Chinese children's mathematical ability. *British Journal of Educational Psychology*, *87*, 328-344. https://doi.org/10.1111/bjep.12152

Hubbard, E. M., Piazza, M., Pinel, P., & Dehaene, S. (2005). Interactions between number and space in parietal cortex. *Nature Reviews Neuroscience, 6*, 435. https://doi.org/10.1038/nrn1684

Huntsinger, C. S., Jose, P. E., Larson, S. L., Balsink Krieg, D., & Shaligram, C. (2000). Mathematics, vocabulary, and reading development in Chinese American and European American children over the primary school years. *Journal of Educational Psychology*, *92*, 745. https://doi.org/10.1037/0022-0663.92.4.745

*Huntsinger, C. S., Jose, P. E., & Luo, Z. (2016). Parental facilitation of early mathematics and reading skills and knowledge through encouragement of home-based activities. *Early Childhood Research Quarterly*, *37*, 1-15. https://doi.org/10.1080/016502597384929

Hutchison, J. E., Lyons, I. M., & Ansari, D. (2019). More similar than different: Gender differences in children's basic numerical skills are the exception not the rule. *Child development*, *90*(1), e66-e79. https://doi.org/10.1111/cdev.13044

Jang, H. (2016). Identifying 21st century STEM competencies using workplace data. *Journal of Science Education and Technology*, *25*(2), 284-301. https://doi.org/10.1007/s10956-015-9593-1

Jordan, N. C., Kaplan, D., Nabors Oláh, L., & Locuniak, M. N. (2006). Number sense growth in kindergarten: A longitudinal investigation of children at risk for mathematics difficulties. *Child Development*, *77*(1), 153-175. https://doi.org/10.1111/j.1467-8624.2006.00862.x

Jordan, N. C., Kaplan, D., Ramineni, C., & Locuniak, M. N. (2009). Early math matters: Kindergarten number competence and later mathematics outcomes. *Developmental Psychology, 45*, 850–867. https://doi.org/10.1037/a0014939

*Khanolainen, D., Psyridou, M., Silinskas, G., Lerkkanen, M. K., Niemi, P., Poikkeus, A. M., & Torppa, M. (2020). Longitudinal effects of the home learning environment and parental difficulties on reading and math development across grades 1–9. *Frontiers in Psychology, 11, 1-20*. https://doi.org/10.3389/fpsyg.2020.577981

*Kleemans, T., Peeters, M., Segers, E., & Verhoeven, L. (2012). Child and home predictors of early numeracy skills in kindergarten. *Early Childhood Research Quarterly*, *27*(3), 471-477. https://doi.org/10.1016/j.ecresq.2011.12.004

*Kleemans, T., Segers, E., & Verhoeven, L. (2018). Individual differences in basic arithmetic skills in children with and without developmental language disorder: Role of home numeracy experiences. *Early Childhood Research Quarterly*, *43*, 62-72. https://doi.org/10.1016/j.ecresq.2018.01.005

Klein, A., Starkey, P., & Wakeley, A. (2000). *Child Math Assessment: Preschool battery (cma). Berkeley, CA: University of California*.

Krinzinger, H., Kaufmann, L., Gregoire, J., Desoete, A., Nuerk, H. C., & Willmes, K. (2012). Gender differences in the development of numerical skills in four European countries. International Journal of Gender, Science and Technology, 4, 62–77. http://genderandset. open.ac.uk/index.php/genderandset/article/view/155

*LeFevre, J. A., Polyzoi, E., Skwarchuk, S. L., Fast, L., & Sowinski, C. (2010). Do home numeracy and literacy practices of Greek and Canadian parents predict the numeracy skills of kindergarten children? *International Journal of Early Years Education*, *18*(1), 55-70. https://doi.org/10.1080/09669761003693926

*LeFevre, J., Skwarchuk, S. L., Smith-Chant, B. L., Fast, L., Kamawar, D., & Bisanz, J. (2009). Home numeracy experiences and children’s math performance in the early school years. *Canadian*

Journal of Behavioural Science/Revue Canadienne Des Sciences Du Comportement, 41, 55–66. https://doi.org/10.1037/a0014532

LeFevre, J. A., Smith-Chant, B. L., Fast, L., Skwarchuk, S. L., Sargla, E., Arnup, J. S., Penner-Wilger, M., Bisanz, J., & Kamawar, D. (2006). What counts as knowing? The development of conceptual and procedural knowledge of counting from kindergarten through grade 2. *Journal of Experimental Child Psychology*, *93*(4), 285-303. https://doi.org/10.1016/j.jecp.2005.11.002

*Lehrl, S., Ebert, S., Blaurock, S., Rossbach, H. G., & Weinert, S. (2020). Long-term and domain-specific relations between the early years home learning environment and students' academic outcomes in secondary school. *School Effectiveness and School Improvement*, *31*(1), 102-124. https://doi.org/10.1080/09243453.2019.1618346

Levine, S. C., Foley, A., Lourenco, S., Ehrlich, S., & Ratliff, K. (2016). Sex differences in spatial cognition: Advancing the conversation. *WIREs Cognitive Science, 7*, 127-155. https://doi.org/10.1002/wcs.1380

Levine, S. C., Gibson, D. J., & Berkowitz, T. (2019). Mathematical development in the early home environment. In *Cognitive Foundations for Improving Mathematical Learning* (pp. 107-142). Academic Press.

*Levine, S. C., Suriyakham, L. W., Rowe, M. L., Huttenlocher, J., & Gunderson, E. A. (2010). What counts in the development of young children's number knowledge?. *Developmental Psychology*, *46*(5), 1309-1319. https://doi.org/10.1037/a0019671

*Leyva, D. (2019). How Do Low-Income Chilean Parents Support Their Preschoolers' Writing and Math Skills in a Grocery Game?. *Early Education and Development*, *30*(1), 114-130. https://doi.org/10.1080/10409289.2018.1540250

*Leyva, D., Tamis-LeMonda, C. S., Yoshikawa, H., Jimenez-Robbins, C., & Malachowski, L. (2017). Grocery games: How ethnically diverse low-income mothers support children's reading and mathematics. *Early Childhood Research Quarterly*, *40*, 63-76. https://doi.org/10.1016/j.ecresq.2017.01.001

*Liu, Y., Zhang, X., Song, Z., & Yang, W. (2019). The unique role of father–child numeracy activities in number competence of very young Chinese children. *Infant and Child Development*, *28*(4), e2135. https://doi.org/10.1002/icd.2135

*Lombardi, C. M., Casey, B. M., Thomson, D., Nguyen, H. N., & Dearing, E. (2017). Maternal support of young children's planning and spatial concept learning as predictors of later math (and reading) achievement. *Early Childhood Research Quarterly*, *41*, 114-125. https://doi.org/10.1016/j.ecresq.2017.07.004

*Lombardi, C. M., & Dearing, E. (2021). Maternal support of children's math learning in associations between family income and math school readiness. *Child Development, 92*(1), 1-17. https://doi.org/10.1111/cdev.13436

OECD. (2018). Equity in education: Breaking down barriers to social mobility. PISA, OECD Publishing, Paris. https://doi.org/10.1787/9789264073234-en

OECD (2019). Mathematics performance (PISA) (indicator). https://doi.org/10.1787/04711c74-en (Accessed on 27 August 2019).

Ma, X., Shen, J., Krenn, H. Y., Hu, S., & Yuan, J. (2016). A meta-analysis of the relationship between learning outcomes and parental involvement during early childhood education and early elementary education. *Educational Psychology Review*, *28*, 771-801. https://doi.org/10.1007/s10648-015-9351-1

Ma, L. L., Wang, Y. Y., Yang, Z. H., Huang, D., Weng, H., & Zeng, X. T. (2020). Methodological quality (risk of bias) assessment tools for primary and secondary medical studies: what are they and which is better? *Military Medical Research*, *7*(1), 1-11 https://doi.org/10.1186/s40779-020-00238-8

*Manolitsis, G., Georgiou, G. K., & Tziraki, N. (2013). Examining the effects of home literacy and numeracy environment on early reading and math acquisition. *Early Childhood Research Quarterly*, *28*(4), 692-703. https://doi.org/10.1016/j.ecresq.2013.05.004

Mensah, F. K., & Kiernan, K. E. (2010). Gender differences in educational attainment: influences of the family environment. *British Educational Research Journal*, *36*(2), 239-260. https://doi.org/10.1080/01411920902802198

*Missall, K., Hojnoski, R. L., Caskie, G. I., & Repasky, P. (2015). Home numeracy environments of preschoolers: Examining relations among mathematical activities, parent mathematical beliefs, and early mathematical skills. *Early Education and Development*, *26*(3), 356-376. https://doi.org/10.1080/10409289.2015.968243

Mix, K. S., & Cheng, Y. L. (2012). The relation between space and math: Developmental and educational implications. *Advances in Child Development and Behavior*, *42*, 197-243. https://doi.org/10.1016/B978-0-12-394388-0.00006-X

Moffatt, L., Anderson, A., Anderson, J., & Shapiro, J. (2009). Gender and mathematics at play: Parents' constructions of their preschoolers mathematical capabilities. *Investigations in Mathematics Learning, 2*(1), 1-25. https://doi.org/10.1080/24727466.2009.11790288

Moola, S., Munn, Z., Tufanaru, C., Aromataris, E., Sears, K., Sfetcu, R., Currie, M., Qureshi, R., Mattis, P., Lisy, K., & Mu, P-F. (2020). Chapter 7: Systematic reviews of etiology and risk. In E.

Aromataris & Z. Munn Z (Eds.), *JBI Manual for Evidence Synthesis.* https://synthesismanual.jbi.global

Muñez, D., Bull, R., & Lee, K. (2021). Socioeconomic status, home mathematics environment and math achievement in kindergarten: A mediation analysis. *Developmental Science*, *24*(6), e13135. https://doi.org/10.1111/desc.13135

Munn, Z., Barker, T. H., Moola, S., Tufanaru, C., Stern, C., McArthur, A., ... & Aromataris, E. (2020). Methodological quality of case series studies: an introduction to the JBI critical appraisal tool. *JBI Evidence Synthesis*, *18*(10), 2127-2133. https://journals.lww.com/jbisrir/Fulltext/2020/10000/Methodological_quality_of_case_series_studies__an.5.aspx?context=FeaturedArticles&collectionId=2

*Napoli, A. R., & Purpura, D. J. (2018). The home literacy and numeracy environment in preschool: Cross-domain relations of parent–child practices and child outcomes. *Journal of Experimental Child Psychology*, *166*, 581-603. https://doi.org/10.1016/j.jecp.2017.10.002

Neitzel, C., & Dopkins Stright, A. (2004). Parenting behaviours during child problem solving: The roles of child temperament, mother education and personality, and the problem-solving context. *International Journal of Behavioral Development*, *28*, 166-179. https://doi.org/10.1080/01650250344000370

NICHD Early Child Care Research Network. (1999). Child care and mother-child interaction in the first three years of life. *Developmental Psychology, 35*, 1399-1413. doi: 10.1037/0012-1649.35.6.1399

NICHD Early Child Care Research Network (Ed.). (2005). *Child care and child development: Results from the NICHD study of early child care and youth development.* Guilford Press.

*Niklas, F., & Schneider, W. (2014). Casting the die before the die is cast: The importance of the home numeracy environment for preschool children. *European Journal of Psychology of Education, 29*(3), 327-345. https://doi.org/10.1007/s10212-013-0201-6

Ostrov, J. M., & Hart, E. J. (2013). Observational methods. *The Oxford handbook of quantitative methods in psychology (Ed T.D. Little)*, *1*, 286-304.Oxford, UK: Oxford University Press.

*Pan, Y., Gauvain, M., Liu, Z., & Cheng, L. (2006). American and Chinese parental involvement in young children's mathematics learning. *Cognitive Development*, *21*(1), 17-35. https://doi.org/10.1016/j.cogdev.2005.08.001

Papic, M. M., Mulligan, J. T., & Mitchelmore, M. C. (2011). Assessing the development of preschoolers' mathematical patterning. *Journal for Research in Mathematics Education, 42*, 237–268. https://doi.org/10.5951/jresematheduc.42.3.0237

Peng, P., Lin, X., Ünal, Z. E., Lee, K., Namkung, J., Chow, J., & Sales, A. (2020). Examining the mutual relations between language and mathematics: A meta-analysis. *Psychological Bulletin, 146*(7), 595–634. https://doi.org/10.1037/bul0000231

Perry, B. & Dockett, S. (2018). Using a bioecological framework to investigate an early childhood mathematics education intervention. *European Early Childhood Education Research Journal, 26*:4, 604-617. https://doi.org/10.1080/1350293X.2018.1487161

*Purpura, D. J., King, Y. A., Rolan, E., Hornburg, C. B., Schmitt, S. A., Hart, S. A., & Ganley, C. M. (2020). Examining the factor structure of the home mathematics environment to delineate its role in predicting preschool numeracy, mathematical language, and spatial skills. *Frontiers in Psychology, 11*, 1-14. https://doi.org/10.3389/fpsyg.2020.01925

Pustejovsky, J. E. (2017). *clubSandwich: Cluster-robust (sandwich) variance estimators with small-sample corrections*. Retrieved from https://cran.r-project.org/%0Apackage=clubSandwich

Pustejovsky, J. E., & Tipton, E. (2021). Meta-analysis with robust variance estimation: Expanding the range of working models. *Prevention Science*, 1-14. http://doi.org/10.1007/s11121-021-01246-3

R Core Team. (2020). R: *A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.Rproject.org/

*Ramani, G. B., Rowe, M. L., Eason, S. H., & Leech, K. A. (2015). Math talk during informal learning activities in Head Start families. *Cognitive Development*, *35*, 15-33. https://doi.org/10.1016/j.cogdev.2014.11.002

Ramani, G. B., & Siegler, R. S. (2014). How informal learning activities can promote children's numerical knowledge. *The Oxford Handbook of Numerical Cognition*, 1135-1154.

Reilly, D., Neumann, D. L., & Andrews, G. (2015). Sex differences in mathematics and science achievement: A meta-analysis of National Assessment of Educational Progress assessments. *Journal of Educational Psychology, 107*, 645-662. https://doi.org/10.1037/edu0000012

Reyna, V. F., Nelson, W., Han, P., & Dieckmann, N. F. (2009). How numeracy influences risk comprehension and medical decision making. *Psychological Bulletin, 135,* 943–973. https://doi.org/10.1037/a0017327

*Ribeiro, L. A., Casey, B., Dearing, E., Nordahl, K. B., Aguiar, C., & Zachrisson, H. (2020). Early maternal spatial support for toddlers and math skills in second grade. *Journal of Cognition and Development, 21*(2), 282-311. https://doi.org/10.1080/15248372.2020.1717494

Ritchie, S. J., & Bates, T. C. (2013). Enduring links from childhood mathematics and reading achievement to adult socioeconomic status. *Psychological Science, 24*, 1301–1308. https://doi.org/10.1177/0956797612466268.

Rittle-Johnson, B., Zippert, E. L., & Boice, K. L. (2019). The roles of patterning and spatial skills in early mathematics development. *Early Childhood Research Quarterly, 46*, 166-178. https://doi.org/10.1016/j.ecresq.2018.03.006

Rosselli, M., Ardila, A., Matute, E., & Inozemtseva, O. (2009). Gender differences and cognitive correlates of mathematical skills in school-aged children. Child Neuropsychology, 15, 216–231. https://doi.org/10.1080/ 09297040802195205

*Segers, E., Kleemans, T., & Verhoeven, L. (2015). Role of parent literacy and numeracy expectations and activities in predicting early numeracy skills. *Mathematical Thinking and Learning*, *17*(2-3), 219-236. https://doi.org/10.1080/10986065.2015.1016819

*Silver, A. M., Elliott, L., Imbeah, A., & Libertus, M. E. (2020). Understanding the unique contributions of home numeracy, inhibitory control, the approximate number system, and spontaneous focusing on number for children's math abilities. *Mathematical Thinking and Learning*, *22*(4), 296-311. https://doi.org/10.1080/10986065.2020.1818469

*Skwarchuk, S. L., Sowinski, C., & LeFevre, J. A. (2014). Formal and informal home learning activities in relation to children's early numeracy and literacy skills: The development of a home numeracy model. *Journal of Experimental Child Psychology*, *121*, 63-84. https://doi.org/10.1016/j.jecp.2013.11.006

*Son, S. C., & Hur, J. H. (2020). Parental math talk during home cooking and math skills in head start children: The role of task management talk. *Journal of Research in Childhood Education, 34*(3), 406-426. https://doi.org/10.1080/02568543.2019.1704318

Shonkoff, J. P., & Phillips, D. A. (2000). *Rethinking nature and nurture: From neurons to neighborhoods*. National Academy Press.

Stanley, T. D. (2008). Meta-regression methods for detecting and estimating empirical effects in the presence of publication selection. *Oxford Bulletin of Economics and Statistics, 70*(1), 103–127. https://doi.org/10.1111/j.1468-0084.2007.00487.x

Stanley, T. D. (2017). Limitations of PET-PEESE and other meta-analysis methods. *Social Psychological and Personality Science, 8*(5), 581-591. https://doi.org/10.1177/1948550617693062

Stanley, T. D., & Doucouliagos, H. (2014). Meta-regression approximations to reduce publication selection bias. *Research Methods, 5*(1), 60-78. https://doi.org/10.1002/jrsm.1095

Starkey, P., & Klein, A. (2000). Fostering parental support for children's mathematical development: An intervention with Head Start families. *Early Education & Development, 11*, 659–680. https://doi.org/10.1207/s15566935eed1105

Starkey, P., Klein, A., & Wakeley, A. (2004). Enhancing young children's mathematical knowledge through a pre-kindergarten mathematics intervention. *Early childhood research quarterly, 19*(1), 99-120. https://doi.org/10.1016/j.ecresq.2004.01.002

Stroup, D. F., Berlin, J. A., Morton, S. C., Olkin, I., Williamson, G. D., Rennie, D., & Thacker, S. B. (2000). Meta-analysis of observational studies. *JAMA*, *283*(15), 2008–2012. https://doi.org/10.1007/978-94-007-3024-3_10

*Susperreguy, M. I., & Davis-Kean, P. E. (2016). Maternal math talk in the home and math skills in preschool children. *Early Education and Development*, *27*, 841-857. http://dx.doi.org/10.1080/10409289.2016.1148480

Susperreguy, M. I., Douglas, H., Xu, C., Molina-Rojas, N., & LeFevre, J. A. (2020). Expanding the Home Numeracy Model to Chilean children: Relations among parental expectations, attitudes, activities, and children's mathematical outcomes. *Early Childhood Research Quarterly*, *50*, 16-

28. https://doi.org/10.1016/j.ecresq.2018.06.010

*Susperreguy, M. I., Di Lonardo Burr, S., Xu, C., Douglas, H., & LeFevre, J. A. (2020). Children's home numeracy environment predicts growth of their early mathematical skills in kindergarten. *Child Development*, *91*(5), 1663-1680. https://doi.org/10.1111/cdev.13353

*Thippana, J., Elliott, L., Gehman, S., Libertus, K., & Libertus, M. E. (2020). Parents' use of number talk with young children: Comparing methods, family factors, activity contexts, and relations to math skills. *Early Childhood Research Quarterly, 53*, 249-259. https://doi.org/10.1016/j.ecresq.2020.05.002

*Thompson, R. J., Napoli, A. R., & Purpura, D. J. (2017). Age-related differences in the relation between the home numeracy environment and numeracy skills. *Infant and Child Development*, *26*(5), e2019. https://doi.org/10.1002/icd.2019

Tipton, E., & Pustejovsky, J. E. (2015). Small-sample adjustments for tests of moderators and model fit using robust variance estimation in meta-regression. *Journal of Educational and Behavioral Statistics, 40*(6), 604-634.

Tudge, J. R., Mokrova, I., Hatfield, B. E., & Karnik, R. B. (2009). Uses and misuses of Bronfenbrenner's bioecological theory of human development. *Journal of Family Theory & Review*, *1*(4), 198-210.

U.S. Department of Education (2016). *STEM 2026: A vision for innovation in STEM education.* Washington, DC: Office of Innovation and Improvement.

Vandermaas-Peeler, M., Boomgarden, E., Finn, L., & Pittard, C. (2012). Parental support of numeracy during a cooking activity with four-year-olds. *International Journal of Early Years Education*, *20*, 78-93. https://doi.org/10.1080/09669760.2012.663237

*Vandermaas-Peeler, M., & Pittard, C. (2014). Influences of social context on parent guidance and low-income preschoolers' independent and guided math performance. *Early Child Development and Care*, *184*(4), 500-521. https://doi.org/10.1080/03004430.2013.799155

*Vasilyeva, M., Laski, E., Veraksa, A., Weber, L., & Bukhalenkova, D. (2018). Distinct pathways from parental beliefs and practices to children's numeric skills. *Journal of Cognition and Development*, *19*(4), 345-366. https://doi.org/10.1080/15248372.2018.1483371

Verdine, B. N., Golinkoff, R. M., Hirsh-Pasek, K., & Newcombe, N. S. (2014). Finding the missing piece: Blocks, puzzles, and shapes fuel school readiness. *Trends in Neuroscience and Education*, *3*, 7-13. https://doi.org/10.1016/j.tine.2014.02.005

Verdine, B., Golinkoff, R. M., Hirsh-Pasek, K., & Newcombe, N. (2017). Links between spatial and mathematical skills across the preschool years. In press *Monographs of the Society for Research in Child Development*, *82*(1), 81–88. https://doi.org/10.1111/mono.12284

Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor package. *Journal of statistical software*, *36*(3), 1-48.

Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology*, *101(4)*, 817-835. https://doi.org/10.1037/a0016127

Wei, T., Liu, X., & Barnard-Brak, L. (2015). Gender differences in mathematics and reading trajectories among children from kindergarten to eighth grade. *Research in Education, 93*, 77–89. https://doi.org/10.7227/RIE.0015

Wei, W., Lu, H., Zhao, H., Chen, C., Dong, Q., & Zhou, X. (2012). Gender differences in children's arithmetic performance are accounted for by gender differences in language abilities. Psychological Science, 23, 320–330. https://doi.org/10.1177/0956797611427168

Woodcock, R. W., Mather, N., McGrew, K. S., & Wendling, B. J. (2001). *Woodcock-Johnson III tests of cognitive abilities* (pp. 371-401). Itasca, IL: Riverside Publishing Company.

*Yildiz, B.M., Sasanguie, D., De Smedt, B., & Reynvoet, B. (2018a). Investigating the relationship between two home numeracy measures: A questionnaire and observations during Lego building and book reading. *British Journal of Developmental Psychology*, *36*(2), 354-370. https://doi.org/10.1111/bjdp.12235

*Yıldız, B.M., Sasanguie, D., De Smedt, B., & Reynvoet, B. (2018b). Frequency of home numeracy activities is differentially related to basic number processing and calculation skills in kindergartners. *Frontiers in Psychology*, *9*, 340. https://doi.org/10.3389/fpsyg.2018.00340

Yıldız, B.M., Sasanguie, D., De Smedt, B., & Reynvoet, B. (2020). Probing the relationship between home numeracy and children's mathematical skills: A systematic review. *Frontiers in Psychology*, *11*, 2074. https://doi.org/10.3389/fpsyg.2020.02074

*Zhang, X., Hu, B. Y., Zou, X., & Ren, L. (2020). Parent–child number application activities predict children’s math trajectories from preschool to primary school. *Journal of Educational Psychology*, *112*(8) 1521–1531. http://dx.doi.org/10.1037/edu0000457

*Zippert, E. & Rittle-Johnson, B. (2018). The home math environment: More than numeracy. *Early Childhood Research Quarterly.* https://doi.org/10.1016/j.ecresq.2018.07.009

Zippert, E. L., & Rittle-Johnson, B. (2020). The home math environment: More than numeracy. *Early Childhood Research Quarterly, 50*, 4-15. https://doi.org/10.1016/j.ecresq.2018.07.009

Table 1. Examples of relevant assessments of *i*) parental math support in the home (exposure) and *ii*) children's math skills (outcome).

Assessments of parent math /spatial support	**Math outcomes**
Parents' Home Numeracy Questionnaire, a paper-and-pencil questionnaire, developed by Skwarchuk et al. (2014)	The Test of Early Mathematics Achievement 3rd edition: TEMA-3 (Ginsburg & Baroody, 2003)
Early math questionnaire (EMQ), 36 questions focusing on mathematics-related activities (Missall et al., 2015)	The WJ-III Applied Problems subtest math (Woodcock et al., 2001)
Parent report of frequency of 12 specific types of activities (e.g., store-bought games involving math, playing with math-related toys, playing with blocks or other construction toys) (DeFlorio, & Beliakoff, 2015)	Bracken Basic Concepts Scale third edition (quantitative subtest, 19 items assessing math concepts (quantity, part-whole) (Bracken, 2006)
Self-report questionnaires about involvement in 24 numeracy-related activities ranging from formal instruction in specific skills (e.g., printing numbers and learning simple sums) to informal activities involving quantitative content (e.g., talking about money when shopping and measuring ingredients when cooking) (Huang, et al., 2017)	Child Math Assessment (CMA), 17 tasks covering a range of mathematical domains, including number sense, arithmetic, geometric reasoning, measurement, and patterns (Klein et al., 2000)
Interview with parents focusing on the frequency of the parent's attempts to teach or encourage the use of number concepts and skills, that is, counting, basic number facts, demonstration of concepts such as seriation, number words, and using words related to number concepts (Blevins-Knabe & Musun-Miller, 1996)	Basic Arithmetic Test (Aunola & Räsänen, 2007)
Encouragement of Academic Skills in Young Children (EASYC) questionnaire, developed following Huntsinger, Jose et al. (2000) cross-cultural study of children's academic achievement.	Individual growth and development indicators of early numeracy (IGDIs-EN) (Hojnoski & Floyd, 2013)
The lady bug game (board game): parents instructed to incorporate numeracy activities while playing, coded for 5 types of numeracy support (Vandermaas-Peele et al., 2012)	16 story problems based on the Story Problems of the Number Competency Core Battery (Jordan, et al., 2009)

Table 2. Characteristics of included trials.

Study, year	Design (CS/L)*	N	Exposure (F/I/FI) **	Outcome
Benigno & Ellis, 2004	CS	19/16	I	Comprehensive Assessment & Counting/Number Knowledge
Casey et al., 2018	L	140	I	Math Problems
Cheung et al., 2018	CS	673	FI	Arithmetic Skills & Counting/Number Knowledge
Cheung et al., 2020	CS	290	FI	Counting/Number Knowledge
De Keyser et al., 2020	L	353	I	Counting/Number Knowledge
DeFlorio & Beliakoff, 2015	CS	178	FI	Comprehensive Assessment
Del Rio et al., 2017	CS	180	F	Math Problems
Elliot et al, 2017	CS	64	I	Comprehensive Assessment
Evans & Field, 2020	L	7263	F	Comprehensive Assessment
Huang et al., 2017	CS	104	FI	Math Problems & Arithmetic Skills
Huntsinger et al., 2016	CS & L	200	FI	Comprehensive Assessment
Khanolainen et al., 2020	L	1590	F	Arithmetic Skills

Kleemans et al., 2012	CS	89	FI	Arithmetic Skills
Kleemans et al., 2018	L	143	FI	Comprehensive Assessment
LeFevre et al., 2009	CS	146	FI	Arithmetic Skills
LeFevre et al., 2010	CS	100/104	F	Counting/Number Knowledge
Lehrl et al., 2020	L	286	FI	Math Problems & Arithmetic Skills
Levine et al., 2010	L	44	I	Counting/Number Knowledge
Leyva, 2019	L	210	I	Math Problems
Leyva et al., 2017	L	212	I	Math problems & Counting/Number Knowledge
Liu et al., 2019	CS	109	FI	Comprehensive Assessment
Lombardi & Dearing, 2020	L	140	I	Math Problems
Lombardi et al., 2017	L	140	I	Math Problems
Manolitis et al., 2013	CS & L	82	F	Arithmetic Skills & Counting/Number Knowledge
Missall et al., 2015	CS	72	I	Comprehensive Assessment & Counting/Number Knowledge
Napoli & Purpura, 2018	CS & L	114	FI	Counting/Number Knowledge

Niklas & Schneider, 2014	L	340	F	Comprehensive Assessment
Pan et al., 2006	CS	32/40	FI	Arithmetic Skills
Purpura et al., 2020	CS	129	I	Math Problems & Counting/Number Knowledge
Ramani et al., 2015	CS	33	F	Comprehensive Assessment
Ribeiro et al., 2020	L	932/129	I	Comprehensive Assessment
Segers et al, 2015	CS	60	F	Comprehensive Assessment
Silver et al., 2020	CS	112	I	Comprehensive Assessment
Skwarchuk et al., 2014	L	121	FI	Arithmetic Skills
Son & Hur, 2020	CS & L	46	I	Comprehensive Assessment
Susperreguy & Davis-Kean, 2016	L	40	I	Comprehensive Assessment
Susperreguy et al., 2020***	CS & L	419	FI	Math Problems & Arithmetic Skills & Counting/Number Knowledge
Thippana et al., 2020	CS	97	FI	Comprehensive Assessment
Thompson et al, 2017	CS	71/113	FI	Counting/Number Knowledge
Vandermaas-Peeler & Pitttard, 2014	CS	18	I	Comprehensive Assessment

Vasiliyeva et al., 2018	L	98	FI	Arithmetic Skills & Counting/Number Knowledge
Yildiz et al., 2018 a)	CS	44	FI	Arithmetic Skills
Yildiz et al., 2018 b)	CS	128	FI	Arithmetic Skills & Counting/Number Knowledge
Zhang et al., 2020	CS & L	196	I	Comprehensive Assessment
Zippert & Rittle-Johnson, 2018	CS & L	63	FI	Comprehensive Assessment

* CS- Cross-sectional; L – Longitudinal; CS & L – Cross-sectional and longitudinal
** F- Formal; I – Informal; FI – Formal and Informal
***: One earlier study by Susperreguy et al. (2020) was eliminated since upon contacting the author, she confirmed that this study, which included T1 and T2 only, was expanded as to include the same data (T1 and T2) but also T3 data. We have just retained the latter, with the longer follow-up.

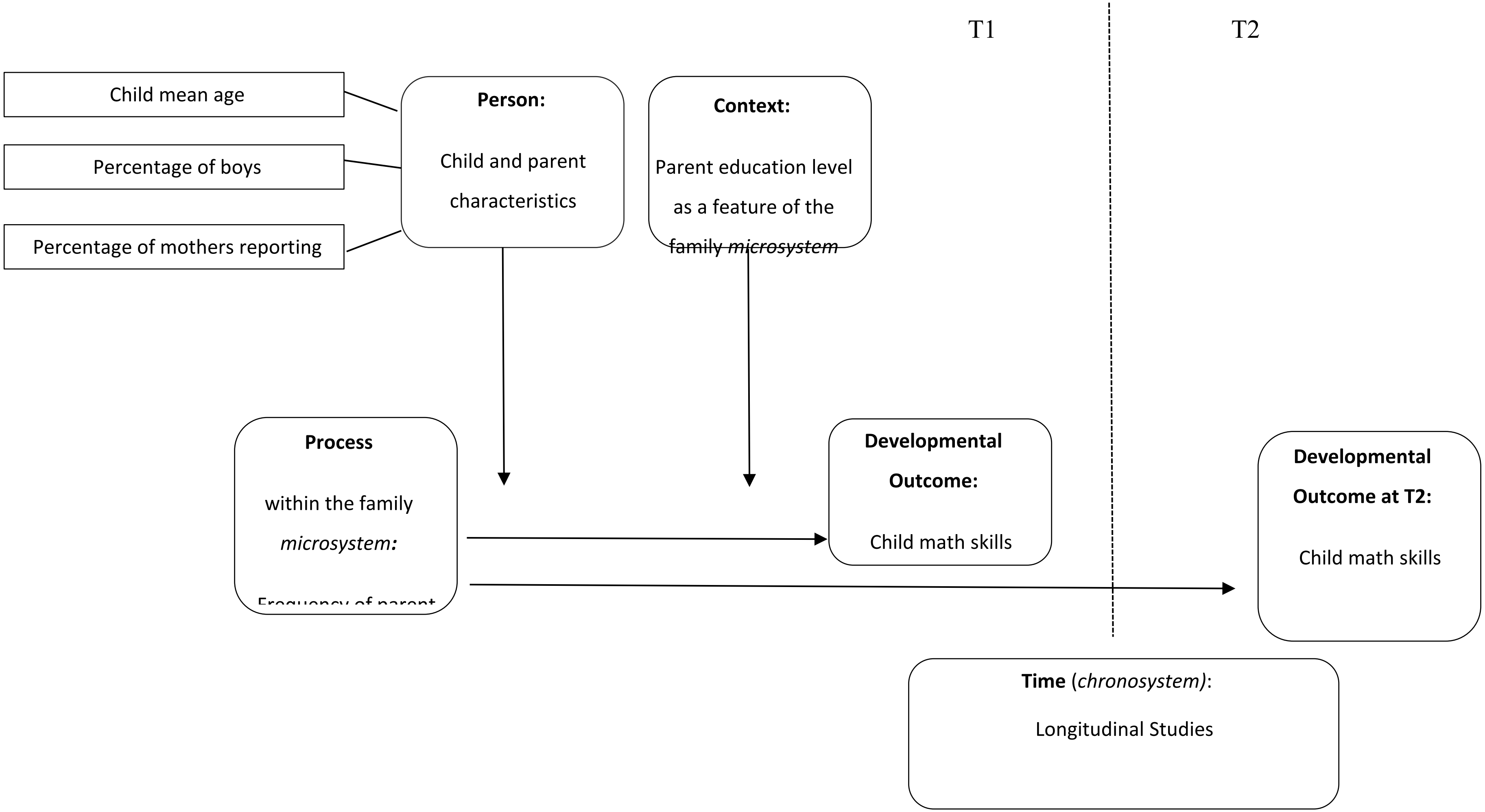

Figure 1: Analytical Model Predicting Children's Math Skills

Note. This model includes variables at the levels of the four defining properties of the bioecological model: Process, Person, Context, and Time. For cross-sectional studies, all variables were measured at T1 and for longitudinal studies, the Developmental Outcome (counting and numerical knowledge, arithmethic skills, comprehensive assessment, and math problems) was measured at T2. Follow-up time ranged from 8 months to 13 years.

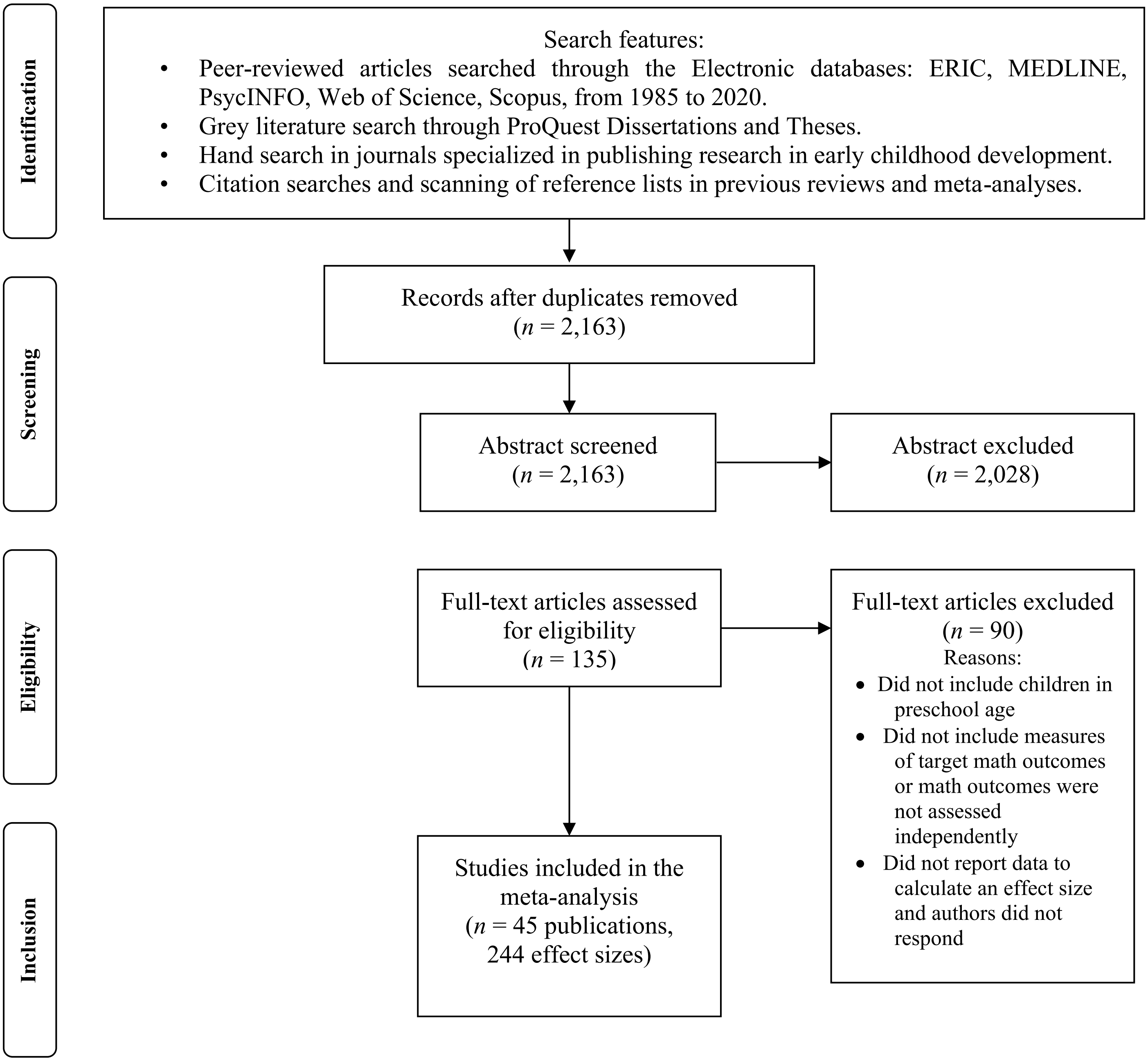

Fig. 2. PRISMA flowchart of the process for identifying trials included in the review.

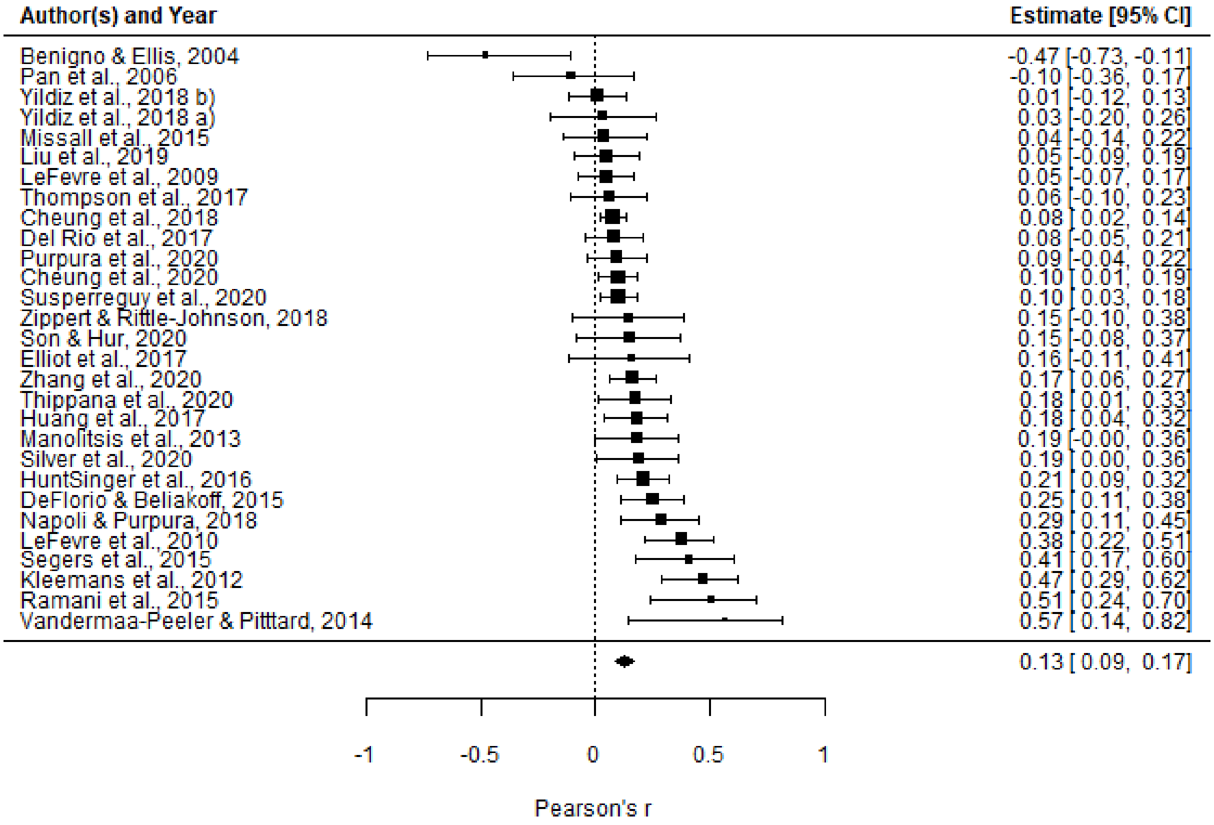

Fig. 3. Forest plot of all effects of interest for the concurrent studies.

Note. Forest plot of the random effect meta-analytical model performed on single effect sizes (Fisher's Z) aggregated by study. In the Figure, effect sizes and CIs are transformed to Pearson's *r* to ease interpretation. Error bars represent 95% CIs of the random effects. The summary diamond represents the overall meta-analytical estimate with its 95% CI.

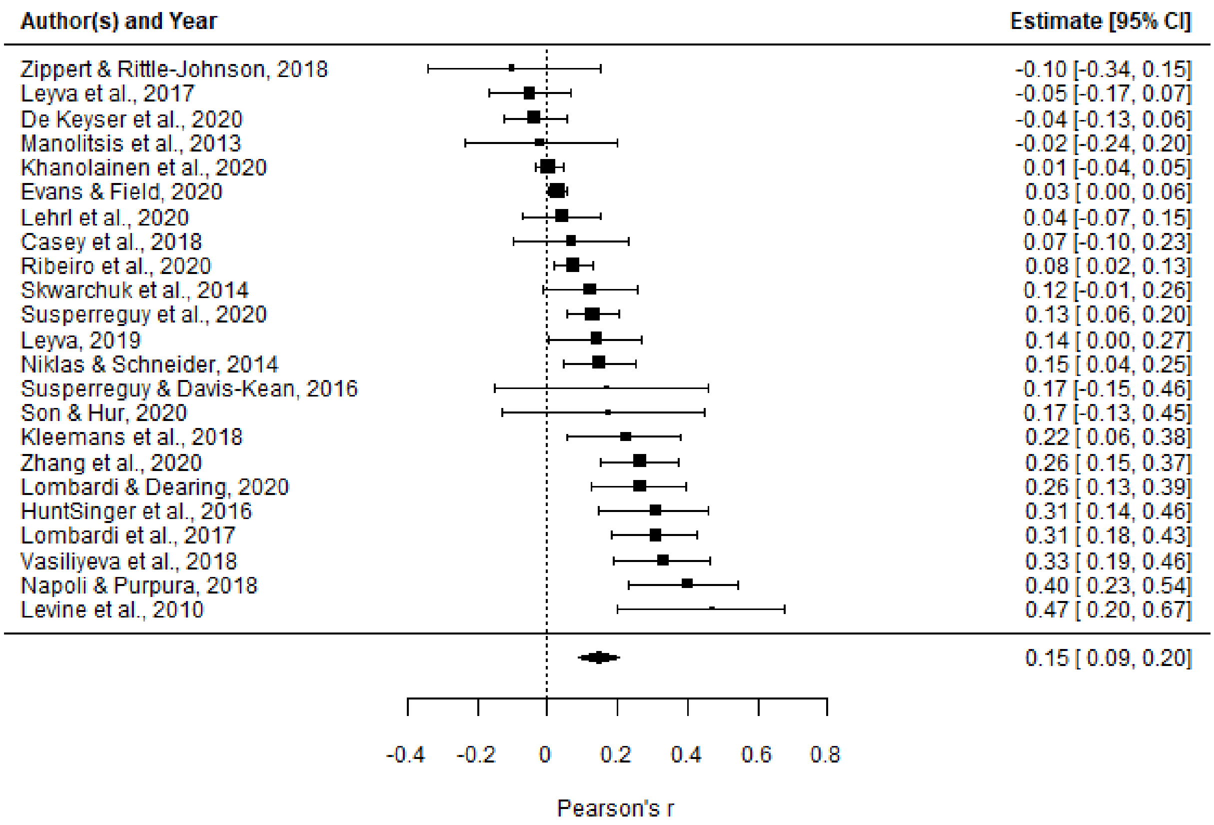

Fig. 4. Forest plot of all effects of interest for the longitudinal studies.

Note. Forest plot of the random effect meta-analytical model performed on single effect sizes (Fisher's Z) aggregated by study. In the Figure, effect sizes and CIs are transformed to Pearson's *r* to ease interpretation. Error bars represent 95% CIs of the random effects. The summary diamond represents the overall meta-analytical estimate with its 95% CI.

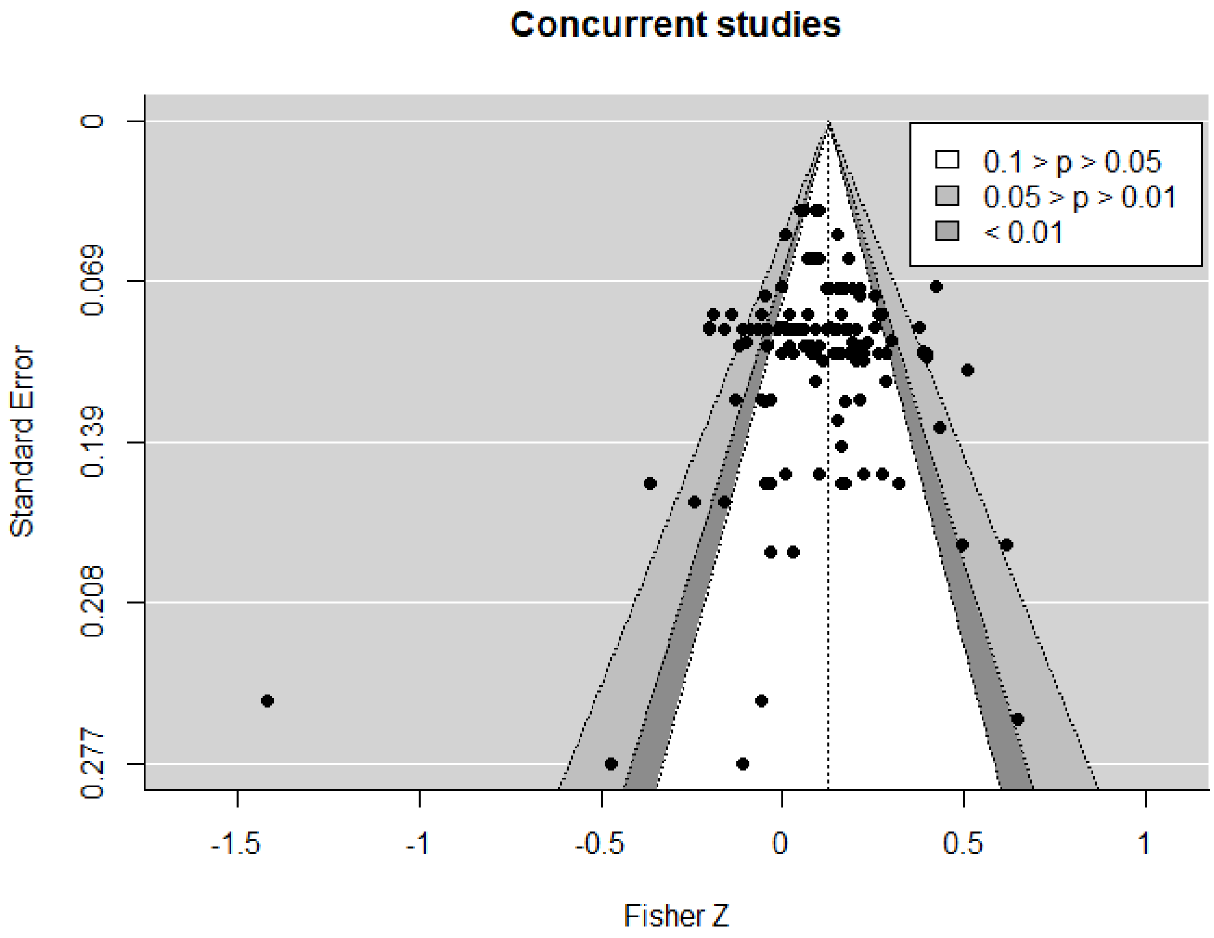

Fig. 5. Funnel plot of all effects of interest for the concurrent studies.

Note. The black dots represent the effect sizes (Fisher's Z). The x axis represents the effect size, and the y axis represents the standard error. The funnel is cantered on the overall estimated effect size, and it indicates the width of the 95% CI of an estimated effect as a function of its standard error.

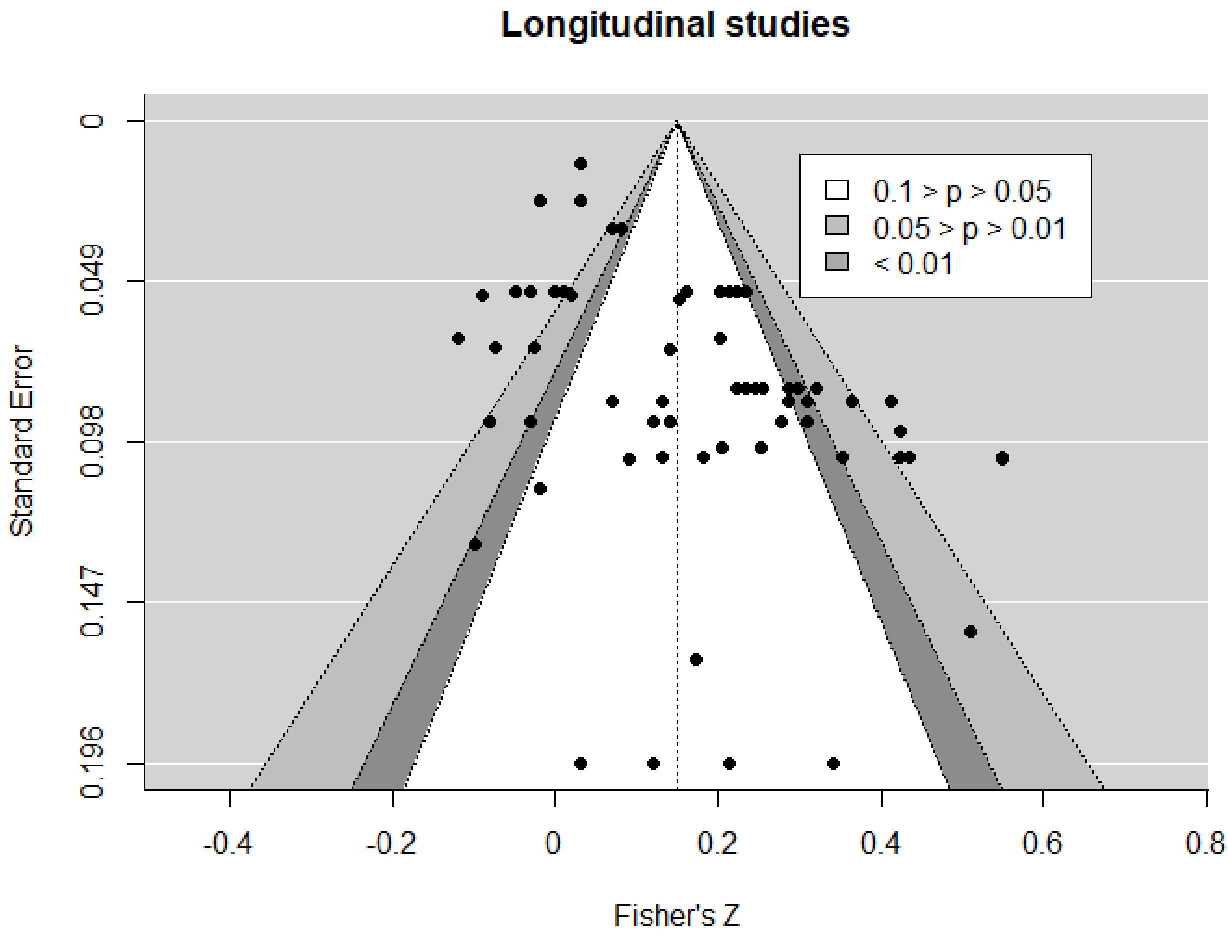

Fig. 6. Funnel plot of all effects of interest for the longitudinal studies.

Note. The black dots represent the effect sizes (Fisher's Z). The x axis represents the effect size, and the y axis represents the standard error. The funnel is cantered on the overall estimated effect size, and it indicates the width of the 95% CI of an estimated effect as a function of its standard error.

Table 1S

Comparison of studies included in the meta-analysis by Daucourt et al. and in the current meta-analysis.

	Authors	Year	Meta-analysis by Daucourt et al.	Current meta-analysis	Exclusion criteria applied in the current meta-analysis
1	Benavides-Varela et al.	2016	●		(2)
2	Benigno & Ellis	2004	●	●	
3	Bennett	2017	●		(2)
4	Bhanot & Jovanovic	2005	●		(1)
5	Cai	2003	●		(1)
6	Cain-Caston	1993	●		(1)
7	Cankaya	2013	●		(3)
8	Casey et al.	2018		●	
9	Cheung & Fong	2019	●		(2)
10	Cheung et al.	2018	●	●	

11	Cheung et al.	2020	●	●	
12	Ciping et al.	2015	●		(1)
13	De Keyser et al.	2020	●	●	
14	DeFlorio & Beliakoff	2015		●	
15	DeFlorio	2011	●		(3)
16	del Río et al.	2017	●	●	
17	Drummond & Stipek	2004	●		(1)
18	Elliott et al.	2017	●	●	
19	Ellis	2020	●		(3)
20	Else-Quest et al.	2008	●		(1,2)
21	Esplin et al.	2016	●		(3)
22	Evans & Field	2020		●	

23	Hart et al.	2016	●		(2)
24	Holod	2012	●		(1,2)
25	Huang et al.	2017	●	●	
26	Huntsinger et al.	2016	●	●	
27	Khanolainen et al.	2020		●	
28	Kleemans et al.	2012	●	●	
29	Kleemans et al.	2013	●		(2)
30	Kleemans et al.	2018	●	●	
31	LeFevre et al.	2009	●	●	
32	LeFevre et al.	2010	●	●	
33	LeFevre et al.	2017	●		(3)
34	Lehrl et al.	2020	●	●	

35	Levine et al.	2010	●	●	
36	Leyva	2019		🔵	
37	Leyva et al.	2017		🔵	
38	Lindberg et al.	2008	●		(1,2)
39	Liu et al.	2019		🔵	
40	Lombardi et al.	2017		🔵	
41	Lombardi & Dearing	2021		🔵	
42	Manolitsis et al.	2013	●	●	
43	Missall et al.	2015	●	●	
46	Napoli & Purpura	2018	●	●	
47	Napoli & Purpura	2020	●		(3)
48	Niklas et al.	2016	●		(2)

49	Niklas et al.	2016	●		(2)
50	Niklas et al.	2016	●		(2)
51	Niklas & Schneider	2014	●	●	
52	Pan et al.	2006		●	
53	Phillipson & Phillipson	2007	●		(1,2)
54	Puccioni	2015	●		(2)
55	Purpura et al.	2020	●	●	
56	Ramani et al.	2015	●	●	
57	Ribeiro et al.	2020		●	
58	Segers et al.	2015	●	●	
59	Silinskas et al.	2010	●		(2)
60	Silver et al.	2020		●	

61	Skwarchuk et al.	2014	●	●	
62	Söchtig & Niklas	2020	●		(3)
63	Son & Hur	2020		🔵	
64	Soto-Calvo et al.	2020	●		(2)
65	Susperreguy & Davis-Kean	2016	●	●	
66	Susperreguy et al.	2018	●		(2)
67	Susperreguy et al.	2020	●	●	
68	Susperreguy et al.	2020	●		(2)
69	Swick	2007	●		(2)
70	Thippana et al.	2020		🔵	
71	Thomson et al.	2020	●		(2)
72	Thompson et al.	2017	●	●	

73	Uscianowski et al.	2020	●		(2)
74	Vandermaas-Peeler et al.	2012	●		(2)
75	Vandermaas-Peeler & Pittard	2014	●	●	
76	Vasilyeva et al.	2018	●	●	
77	Vukovic et al.	2013	●		(1)
78	Yildiz et al.	2018a	●	●	
79	Yıldız et al.	2018b	●	●	
80	Zhang et al.	2020		●	
81	Zippert & Rittle-Johnson	2020	●	●	

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(1) Studies not focusing (or not exclusively focusing) on children aged 3-5

(2) Studies reporting other variables rather than parental support (e.g., involvement, attitudes, beliefs, expectations, stereotypes, perceptions), or not specifically/not only focusing on math support (e.g., intervention supporting literacy and numeracy in the home learning environment)

(3) Studies not accessible/available (e.g., not accessible on databases, presented in scientific events, manuscripts in preparation)