

Predictors of mathematical ability: a meta-analysis and systematic review

Citation

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Review question [1 change]

The central aim of this review is to consolidate the research literature that has examined the relationship between math-related predictors and assessments of mathematical ability.

The specific questions this review aims to answer are:

1. What are the meta-analytic correlations between mathematical ability and its predictors?
2. What is the factor structure of the hypothesized predictors and how much variance do these factors account for in mathematical ability?
3. Will consolidated correlational data support a model of three pathways to mathematics?
4. To what extent are these relationships influenced by other moderating variables, including measures used, executive function, non-verbal and general intelligence, age of assessment, gender, SES and parental education?

Searches

A. Electronic databases

Individual search strategies will be developed and carried out for the following databases and search engines; ERIC (EBSCO), PsycINFO, MEDLINE, Web of Science, Linguistics and Language Behavior Abstracts, ProQuest Dissertations and Theses A&I, Google Scholar, and OpenGrey. This will allow for the identification of both published, peer-reviewed journal articles as well as unpublished or unreviewed reports and other grey literature.

B. Other methods used for identifying relevant research

Through the search of electronic databases, we will identify authors who have published consistently in this field. These authors will be contacted directly and asked if they have knowledge of any unpublished research relevant to this review. Previous review articles with similar inclusion criteria will also be identified and searched for relevant literature.

C. Journals hand searched

In addition to electronic searches, the following journals will be hand searched to identify articles of relevance

Types of study to be included [1 change]

The review will include both concurrent and longitudinal studies. The search will include studies from 1988 - 2018.

Studies should include at least one quantitative measure of mathematical ability and of at least one other associated variable,

at least one correlation between mathematical ability and variable x

OR

percentage of variance (R^2) in mathematical ability accounted for by variable X.

Intervention studies and studies only reporting group differences will be excluded.

Condition or domain being studied

The development of mathematical skill in children and adolescents.

Participants/population [1 change]

The review will focus on children and adolescents aged between 4 and 16. Children should be monolingual, or be part of a sample of primarily monolingual children. No restrictions will be placed on geographical location, or the language of assessment.

Both children considered to have typical development and those identified as having or being at risk of weak number development will be considered. However, the results from these two groups will be treated separately in the analyses to avoid overrepresentation of results from at risk samples.

Atypical samples will not be included in the review. Results from children with identified neurodevelopmental disorders (e.g. autism, Down Syndrome), and from children with identified sensory impairments will therefore be excluded. Samples comprised of over 50% simultaneously or sequentially bilingual children will not be included. Other selected samples such as low-income groups will be excluded.

Studies that do not meet all the above criteria will be excluded from the review. Additionally, case studies and studies with fewer than 15 participants, and studies reporting only qualitative data will not be included.

Intervention(s), exposure(s)

None.

Comparator(s)/control

Not applicable.

Context

Several cognitive systems and abilities such as the approximate number system, early counting skills, language processing and visuo-spatial ability have been found to predict mathematical ability. Each of these have been proposed as individual targets in educational interventions for general mathematical skills, however, longitudinal data indicate that these various predictors are part of a neurologically based system of numerical cognition (Ansari & Karmiloff-Smith, 2002; Chang, Rosenberg-Lee, Metcalfe, Chen, & Menon, 2015; Dehaene 1992). Based on accumulated findings from research on cognition and neuroimaging, Dehaene (1992) and Dehaene, Piazza, Pinel & Cohen (2003) developed a triple-code model

(TCM) of number processing. The TCM has been validated from an interdisciplinary perspective (Schmithorst & Brown, 2004), however, as noted by Siemann & Petermann (2018), a systematic review of the literature on mathematical cognition and the components of the TCM is needed. LeFevre et al., (2010) tested a three pathway model for the acquisition of mathematical skills in pre- and primary school children. In line with Dehaene et al. (2003), the model by LeFevre et al. (2010) defines the linguistic component as directly related to the symbolic number system, and the quantitative component related to magnitude processing. Spatial attention was identified as a supportive skill that relates to both the linguistic and the quantitative component. Using these multiple pathway models of numerical cognition as a theoretical starting point, this systematic review aims to synthesize data from studies with children and adolescents investigating several theorized predictors of mathematical skills.

Main outcome(s) [2 changes]

Current understanding of how children process numbers and how they use early numerical understanding to build core skills in mathematics education is still limited. A systematic review of the literature on mathematical cognition and the components of proposed models of numeracy development such as the triple-code model and the multiple pathway model (Dehaene et al., 2003; LeFevre et al., 2010) is needed to guide future approaches in mathematics education.

The review will lead to a published evaluation in the form of a meta-analysis of the relative impact of each of the described predictors of mathematical ability with relevant moderator variables taken into account. The aim for the data analysis is to perform two-stage meta-analytic structural equation modeling to present a statistically sound evaluation of the collected data.

The most important outcome of this review is increased knowledge of development of numeracy skills which can guide researchers and educators in identifying children at risk and in developing targeted interventions. Because timing and focus is of utmost importance in educational interventions, the analysis of the age-cognition relationship in this systematic review will be a valuable contribution to the fields of education, special needs education and educational psychology.

Measures of effect

Not applicable.

Additional outcome(s) [1 change]

None.

Measures of effect

Not applicable.

Data extraction (selection and coding) [1 change]

The initial step of the review will consist of applying the predefined search strategy to the aforementioned databases and search engines, and importing results into a reference manager software. Duplicates will be identified and removed, and the updated references will be imported into Rayyan, an online software tool to facilitate systematic reviews. Then a full title and abstract screening against the inclusion/exclusion criteria will be carried out for all identified records. This initial stage will first be completed by two screeners, who will both screen the first 25% of references, after which point inter-rater agreement will be assessed. If agreement is satisfactory (above 85% agreement), the screeners will divide the references and continue. If agreement is not satisfactory, the screeners will discuss disagreements and adjust the screening criteria and procedure to ensure future agreement. In the next phase, the papers will be read in full against inclusion/exclusion criteria. Any uncertainties will be logged and discussed between screeners. Information from included records will then be coded.

For studies that meet screening criteria, the following data will be extracted:

Reference, location of study, sample size, age at first assessment point, age at second testing point in longitudinal studies.

- Predictor measures:

Number processing: name of test (e.g number identification test, number sequence production), cognitive component(s) assessed, standardised or researcher made;

Language skills: name of test (e.g rime awareness test, phonemic awareness test), cognitive component(s) assessed, standardised or researcher made

Spatial ability: name of test (mental rotation test, mental paper folding, Corsi blocks), cognitive component(s) assessed, standardised or researcher made

- Outcome measures:

Mathematical competence including

Lower order mathematical skill (as measured in early numeracy tasks) & Higher order mathematical skill

- Quality score
- Statistics: Bivariate correlation between the predictors and mathematical ability OR percentage of variance

Risk of bias (quality) assessment

Risk of bias will be assessed using a criteria established by Hjetland, Brinchmann, Scherer, & Melby-Lervåg (2017). Each selected article will receive a quality score which will be used as a mediator in the meta-analyses. Articles will be assessed against the following criteria.

Sampling: convenience vs. random

Instrument quality: standardized vs. research-designed

Whether alpha test reliability is reported

Published or unpublished study

Whether there are any floor or ceiling effects on any measure: a measure has a floor

effect if the mean value minus the standard deviation exceeds the value of 0.

Moreover, a measure has a ceiling effect if the mean value plus the standard deviation exceeds the maximum possible value on a given measure. Information regarding the number of items on a measure must be provided in the article (or in the manual) in order to establish a presence of ceiling effect.

The percentage of study attrition between the two time points in longitudinal studies.

Strategy for data synthesis

The aim for the data analysis is to perform two-stage meta-analytic structural equation modeling (MASEM) in the statistical software R. This is provided that the review includes an adequate number of studies and that the data aligns with the hypothesized theoretical model. We will also use the software CMA (Comprehensive Meta-Analysis) for bivariate relationships and moderators of those.

Analysis of subgroups or subsets

Both children considered to have typical development and those identified as having or being at risk of weak number development will be considered. However, the results from these two groups will be treated separately in the analyses to avoid over-representation of results from at risk samples.

Contact details for further information

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Review team members and their organisational affiliations [2 changes]

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Type and method of review

Meta-analysis, Systematic review

Anticipated or actual start date

24 September 2018

Anticipated completion date [1 change]

01 September 2022

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Conflicts of interest

Language

English

Country

Norway

Stage of review [2 changes]

Review Completed not published

Subject index terms status

Subject indexing assigned by CRD

Subject index terms

Child; Cognition; Humans

Date of registration in PROSPERO

16 October 2018

Date of first submission

28 September 2018

Stage of review at time of this submission [4 changes]

Stage	Started	Completed
Preliminary searches	Yes	Yes
Piloting of the study selection process	Yes	Yes
Formal screening of search results against eligibility criteria	Yes	Yes
Data extraction	Yes	Yes
Risk of bias (quality) assessment	Yes	Yes
Data analysis	Yes	Yes

Revision note

An addition co-author has been added to the list of contributors

The record owner confirms that the information they have supplied for this submission is accurate and complete and they understand that deliberate provision of inaccurate information or omission of data may be construed as scientific misconduct.

The record owner confirms that they will update the status of the review when it is completed and will add publication details in due course.

Versions

16 October 2018

26 February 2020

18 January 2021

20 June 2022

02 November 2022