Understanding the Cognitive Deficits Related to Mathematics Difficulties: A Meta-Analysis

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Introduction

While mathematical competency is critical for competing successfully in today's high technology world, learning mathematics is a big challenge for many children. Converging evidence shows that approximately 6% of the school-aged population show some form of mathematics difficulties (MD) even with average or higher IQ and adequate instruction (Berch & Mazzocco, 2007; Geary, 2011). Despite the prevalence of MD, MD is much less studied compared to reading difficulties (RD) (Gersten, Clarke, & Mazzocco, 2007). In recent years, an increasing number of studies have examined the factors associated with MD and suggested two major approaches to understanding the deficit profiles of MD. One is through the investigation of deficits in domain-specific skills (Geary, 1993; Gersten et al., 2005). The other is through the investigation of deficits in domain-general cognitive skills (e.g., Johnson, Humphrey, Mellard, Woods, & Swanson, 2010; Peng & Fuchs, 2016; Swanson & Jerman, 2006).

Regarding the domain-specific skill deficits among MD, there is a consensus that MD is related to deficits in the numerical processing system. For example, Geary (1993) conducted a literature review of MD research with a focus on conceptual and procedural competencies of arithmetic and suggested that MD is related to deficits in the representation of arithmetic facts from semantic memory, the execution of arithmetic procedures, and visuospatial presentation of numerical information. The synthesis by Gersten et al. (2005) is consistent with Geary (1993), suggesting that the deficits in numerical-related skills, such as magnitude comparison, counting strategies, identification of numbers, and numerical working memory, are important markers for MD.

Regarding the domain-general skill deficits among MD, previous reviews focused on the memory system. Specifically, Swanson and Jerman (2006), and Peng and Fuchs (2016) used meta-analyses to examine the memory deficits of MD among elementary school children. Both reviews indicated that children with MD, regardless of comorbidity in mathematics and reading difficulties (MDRD), suffer from memory deficits. Compared to children with MDRD, children with MD only seem to have more severe visuospatial and numerical memory deficits. Johnson et al. (2010) also studied the deficit profiles of working memory, short-term memory, executive functions, and processing speed of MD. However, due to a limited number of effect sizes (less than 8 effect sizes for each skill), they could not draw a conclusion on these deficit profiles of MD or systematically examine moderators that influence the profiles.

Although previous reviews have advanced our understanding of domain-specific and domain-general deficits of MD, several important questions remain unanswered, which we aimed to address in the present study. Specifically, we examined (1) whether MD is related to deficits in other cognitive skills besides memory deficits, (2) whether the cognitive deficit profiles of MD are influenced by comorbidity (i.e., MDRD vs. MD only), types of MD screening (i.e., calculation vs. problem solving vs. comprehensive mathematics), severity of MD, domains of task (i.e., verbal vs. numerical vs. visuospatial), and age, and (3) whether deficits in low-level cognitive skills (i.e., processing speed and short-term memory) explain the deficits in high-level cognitive skills (e.g., attention, working memory, and executive functions) among MD.

Investigating these questions is both theoretically and practically important. From the theoretical perspective, the deficit profiles in cognitive skills help further understand the nature of MD. That is, besides numerical processing and memory deficits, is MD also related to deficits in other cognitive skills? (Geary, 2005; Mazzocco, 2005). If yes, would this relation reflect the numerical-deficit nature of MD such that cognitive deficits among MD are related to numerical processing specifically? Is there heterogeneity among MD? If yes, does this heterogeneity reflect different cognitive deficit profiles among different types of MD or does this heterogeneity also reflect the changing cognitive deficit profiles as a function of time? Moreover, does MD have deficits in both low-level and high-level cognitive skills? If yes, do deficits in low-level cognitive skills explain the deficits in high-level cognitive skills, as suggested by the bottleneck theory (Salthouse, 1996; Swanson & Sachse-Lee, 2001; Peng, Sun, Li, & Tao, 2012)?

From a practical perspective, answering these questions has implications for MD identification and intervention. Specifically, if the cognitive deficit profiles vary among different types of MD or vary with time, there should be more accurate identification of MD subtypes and thus more individualized instruction for a MD subtype at a specific period of time. Moreover, an increasing number of studies in recent years have investigated whether training high-level cognitive skills (e.g., working memory) improves cognition and whether such improvement transfers to mathematics outcomes (e.g., Holmes, Gathercole, & Dunning, 2009; Kroesbergen, Van't Noordende, & Kolkman, 2014). Although some studies have found training effects on cognitive skills, most have failed to find the transfer effects (e.g., Jacob & Parkinson, 2015; Melby-Lervåg & Hulme, 2013; Morrison & Chein, 2011; Peng & Miller, 2016; Shipstead, Redick, & Engle, 2012). The lack of far transfer has often been discussed as being related to: 1) variability in the types of cognitive training (Jacob & Parkinson, 2015), 2) variability in the domains of task training materials (Peng & Fuchs, 2016), and 3) variability in the population receiving the training (Shipstead et al., 2012). Investigating the moderation effects of types of MD, severity of MD, domains of task, and age on the cognitive deficit profiles of MD can provide empirical evidence that may help address the conflicting findings in the cognitive intervention research.

Methods

Literature Search

Articles for this meta-analysis were identified in three ways. First, a computer search of the Education Resources Information Center (ERIC), ProQuest, and PsycINFO was conducted. We used the earliest possible start date (1920) till June, 2017. The following terms were used to search in full text: (math*AND difficult* OR disabilit*) OR discalcul*. The terms math*, difficult*, disabilit*, discalcul* allow for inclusion of mathematics, difficulties / difficulty / disability / disabilities, dyscalculia / dyscalculic, and so forth. Second, we searched for unpublished literature through Dissertation and Masters Abstract indexes in ProQuest, Cochrane Database of Systematic Reviews, relevant conference programs (e.g., Conference of Society for Research in Child Development; National Council of Teachers of Mathematics Annual Meeting;

Psychology of Mathematics Education Annual Conference). Third, previous relevant reviews (Geary, 1993; Gersten et al., 2005; Peng & Fuchs, 2016; Swanson & Jerman, 2006) were reviewed to include extra articles not identified in the first two search steps. The initial search yielded 908 studies. Two authors of this study then reviewed all studies by titles and abstracts. After excluding the duplicate 22 articles, the remaining 882 articles were closely reviewed using the specific criteria. First, the study had to include a group of individuals with MD and a group of age-matched TD individuals. That is, the study had to report information showing that the MD group scored at least below the 35th percentile or below one standard deviation on mathematics screening measures, which is a common learning disability identification criterion (Swanson & Harris, 2013). Also, the study had to provide information showing that the IQ (non-verbal IQ, verbal IQ, or combination of non-verbal and verbal IQ) of individuals with MD were in the normal range (standardized score 80-120), and the age-matched TD group was comparable to the MD group. We excluded 499 studies that did not meet these criteria. Then, we reviewed the remaining 383 studies to select studies that compared the MD to TD group on measures that tap at least one of the following cognitive skills: phonological processing, processing speed, short-term memory, working memory, attention, visuospatial skills, and executive functions. We excluded another 308 studies that did not meet this criterion. The final sample included 75 studies, including 4 dissertations, 1 book chapter, and 70 peer-reviewed articles.

Coding Procedure and Inter-Rater Reliability

These 75 studies were coded according to the characteristics of participants, mathematics and IQ screening tasks, tasks used to measure phonological processing, processing speed, short-term memory, working memory, visuospatial skills, attention, and executive functions. Not all studies provided sufficient information on the variables of interest for the present study. In case of insufficient information, authors were contacted to obtain the missing information.

Variables were discussed until a consensus was reached between the first and the second author. Then, both authors used the coding system to conduct the final coding of all studies. Across the total variable matrix, the mean inter-rater agreement (i.e., the percentage of agreement indexed by the data points coded in agreement divided by total coded data points) was .98, with the coefficient above .93 for all moderators of interest and all skills investigated in this study. Any disagreements between the raters were resolved by consulting the original article or by discussion.

Missing data. Not all studies provided sufficient information on the variables of interest for the present study. In case of insufficient information, authors were contacted to obtain the missing information. However, if missing data could not be obtained for a particular moderator variable, the study was excluded from that particular moderator analysis but was included in other moderator analyses for which the data were present.

Analytic Strategies

Effect size. Hedges' g, corrected for sample size bias, was used as the measure of effect size. We chose Hedges' g as it provides a better estimate of effect sizes than Cohen's d on small sample sizes (MD profiling research tends to have small sample sizes) (Grissom & Kim, 2005). For studies reporting means, standard deviations, and sample size, the following formulae were used:

$$g^u = g\left(1 - \frac{3}{4(N_{MD} + N_{TD} - 2) - 1}\right)$$

With $g = \frac{\bar{X}_{MD} - \bar{X}_{TD}}{S}$ and $g = \sqrt{\frac{(N_{MD}-1)S_{MD}^2 + (N_{TD}-1)S_{TD}^2}{N_{MD}+N_{TD}-2}}$

in which g^u is the unbiased estimate of Hedge's g, g is Hedges' g as traditionally defined, N_{MD} is the number of participants in the MD group, N_{TD} is the number of participants in the TD group, $\bar{X}_{MD}$ is the mean of the target skill (e.g., working memory) scores for participants in the MD group, $\bar{X}_{TD}$ is the mean of the target skill scores for participants in the TD group, S is the pooled standard deviation of S_{MD}^2 is the variance of target skill scores for the participants in the MD group, and S_{TD}^2 is the variance of target skill scores for the participants in the TD group. Because Cohen's benchmark for effect size is often adopted in educational research (Hill, Bloom, Black, & Lipsey, 2008), especially in the profiling research on children with learning disabilities (Johnson et al., 2010; Peng & Fuchs, 2016), we used Cohen's benchmark (.02 ~.05 means small effects, .50 ~ .80 means medium effects, and > .80 means large effects, Cohen, 1988) to interpret the magnitude of effect sizes.

Effect sizes of deficits on all cognitive skills were estimated for MD in comparison to the TD group. Next, meta-regression analyses were used to examine the moderation effects of types of MD (i.e., comorbidity and types of MD screening), severity of MD, age, and domains of task on the deficit profile for each cognitive skill. For the moderation analyses, each moderator was examined with other moderators simultaneously controlled in one meta-regression model. For moderators that were categorical, we created different sets of dummy codes and entered them into the meta-regression model (Cohen, Cohen, West, & Aiken, 2013). To examine the "bottleneck theory", we controlled for the group differences between MD and TD on processing speed or short-term memory for the group comparison between MD and TD on working memory, attention, or executive functions. Specifically, we first identified studies that provided correlations among at least one low-level cognitive skill and one high-level cognitive skill. Then, controlling for the group difference on the low-level cognitive skill and the correlation between low-level and high level cognitive skills, we calculated the group difference between MD and TD on the high-level cognitive skill, which would be synthesized to indicate the group differences on high-level cognitive skills, partialling out the effects of low-level cognitive skills.

Nested structure of effect sizes. We considered all eligible effect sizes in each study. That is, studies could contribute multiple effect sizes as long as the sample for each effect size was independent. For studies that reported multiple effect sizes from the same sample (e.g., two effect sizes based on two working memory measures were calculated for MD vs. TD in one study), we accounted for the statistical dependencies using the random effects robust standard error estimation technique developed by Hedges, Tipton, and Johnson (2010). This analysis allows for the clustered data (i.e., effect sizes nested within samples) by correcting the study standard errors to take into account the correlations between effect sizes from the same sample. The robust standard error technique requires that an estimate of the mean correlation (ρ) between all the pairs of effect sizes within a cluster be estimated for calculating the between-study sampling variance estimate, τ^2. In all analyses, we estimated τ^2 with ρ =.80; sensitivity analyses showed that the findings were robust across different reasonable estimates of ρ.

Because we included studies from a wide age span and on different mathematics and cognitive skills, we hypothesized that the research body is reporting a distribution of effect sizes with significant between-studies variance, as opposed to a group of studies attempting to estimate one true effect size. Thus, we used a random-effect model for the current study (Lipsey &Wilson, 2001). Weighted, random-effects meta-regression models using Hedges et al.'s (2010) corrections were conducted with ROBUMETA in STATA (Hedberg, 2011) to summarize effect sizes and to examine potential moderators.

Publication bias. Publication bias (the problem of selective publication, in which the decision to publish a study is influenced by its results) was examined using the method of Egger, Smith, Schneider, and Minder (1997) and funnel plot. We did not find a significant publication bias based on Egger et al.'s (1997) publication bias statistics (i.e., the standard errors of correlations did not significantly predict correlations among studies with ROBUMETA in Stata, *ps* > .05), except for the comparisons on phonological processing and working memory, *ps* <.05. Further funnel plot analyses showed reasonable symmetry in all reported comparisons (the significant Egger's test for the comparisons on phonological processing may be due to four outliers and two outliers for working memory). Taken together, Egger's test and funnel plot suggested that there was little influence of publication bias in the data and thus the original dataset was used in all reported analyses. That said, we controlled for the publication type in our moderation analysis to account for any potential effects of publication bias (Rothstein, Sutton, & Borenstein, 2006).

Results

The 75 studies included in the meta-analysis represented a total of 13,001 children (5251 for MD, and 7750 for TD) obtained from 126 independent samples. There were 846 effect sizes that indicated the comparison between MD and TD on phonological processing (108 effect sizes, with 24 effect sizes for manipulation and 84 effect sizes for retrieval), processing speed (47 effect sizes), short-term memory (192 effect sizes), working memory (286 effect sizes), attention (49 effect sizes), visuospatial skills (20 effect sizes), and executive function (144 effect sizes, with 114 effect sizes for inhibition, 11 effect sizes for updating, 19 effect sizes for switching).

The Deficit Profiles of MD

The estimated average effect size indicating the deficits of MD as compared to TD was as follows: phonological processing: Hedges' *g* = -.91, CI95[-1.24, -.57] (Manipulation: Hedges' g = -1.31, CI95[-1.82, -.79]; Retrieval: Hedges' g = -.61, CI95[-.80, -.43]), processing speed: Hedges' *g* = -.90, CI95[-1.08, -.72], short-term memory: Hedges' *g* = -.56, CI95[-.67, -.46], working memory: Hedges' *g* = -.76, CI95[-.88, -.64], visuospatial skills: Hedges' g = -.43, CI95[-.63, -.23], attention: Hedges' *g* = -.72, CI95[-.92, -.52] (Subjective: Hedges' g = -.44, CI95[-73, -.14]; objective: Hedges' g = -.86, CI95[-1.09, -.63]), and executive function: Hedges' *g* = -.50, CI95[-.60, -.39] (Inhibition: Hedges' g = -.37, CI95[-.48, -.26]; Updating: Hedges' g = -.76, CI95[-1.04, -.48]; Switching: Hedges' g = -.75, CI95[-.87, -.63]). To sum, compared to the TD group, the MD group showed severe deficits in phonological processing and processing speed, and moderate deficits in phonological processing-retrieval, short term memory, working memory, visuospatial skills, and executive functions.

Factors that Influence the Deficit Profiles of MD

Next, we examined whether comorbidity, types of MD screening, severity of MD, age, or domains of task influenced the deficit profiles of each cognitive skill of MD. Our findings show that 1) regarding the comorbidity, the MD group showed severe deficits in phonological processing-manipulation and processing speed, and moderate deficits in phonological processing-retrieval, short-term memory, working memory, visuospatial skills, and executive functions. In contrast, the MDRD group showed more severe deficits than MD only group on phonological processing, processing speed, short-term memory, visuospatial skills, and executive functions; 2) Types of MD screening affected the deficit profiles of phonological processing, working memory, and executive functions such that MD identified with word-problem solving difficulties seemed to have less severe deficits on these cognitive skills than those identified with calculation difficulties or comprehensive mathematics difficulties. For MD identified with comprehensive mathematics difficulties, they had more severe numerical working memory deficits than their visuospatial working memory deficits, and they also had more severe phonological processing-manipulation deficits than their retrieval deficits; 3) Severity of MD was only related to the severity of processing speed deficits; 4) Age only affected deficits in phonological processing and attention such that younger individuals with MD suffer from more severe deficits in these skills than older individuals with MD; 5) Domains of task mostly affected the deficit profiles of processing speed and working memory such that deficits on these skills among MD are most severe in the numerical domain; 6) Low-level skills (short-term memory and processing speed) significantly accounted for some (not all) variance in the group differences between MD and TD on high-level skills (working memory, attention, and executive functions).

Discussion

The present study, to our knowledge, was the first meta-analysis that systematically and comprehensively examined the cognitive deficit profiles of MD and the factors that influence these deficit profiles. Findings have theoretical and practice implications for MD. Theoretically, the findings add to our understanding of MD. First, MD suffers from comprehensive cognitive deficits that are not specifically related to numerical processing, with exceptions that deficits in processing speed and working memory are more related to the numerical domain. Thus, the cognitive deficits of MD are generally not affected by domains of materials. Any individual who is identified with MD is likely to suffer from both domain-specific (numerical processing) and domain-general cognitive deficits. Second, MD is a group with heterogeneity, which lies in two aspects. One is that there is heterogeneity among MD subgroups. The MDRD group is different from the MD only group such that the MDRD group demonstrates more severe cognitive deficits. MD identified with different screening measures also differ from each other. Calculation difficulties are related to more severe deficits in phonological processing and working memory and comprehensive mathematics difficulties are related to more severe deficits in executive functions and working memory. The other aspect of heterogeneity of MD is reflected by age. That is, deficits in attention and phonological processing are more severe among younger individuals with MD. This age effect may be attributed to the characteristics of early mathematics learning (or instruction) that emphasizes automatized arithmetic facts retrieval.

Third, previous research suggests that different cut-off points on MD screening may result in MD with different profiles, indicating that MD may be a continuous construct (e.g., Branum-Martin et al., 2013; Murphy et al., 2007). However, the present review found that after controlling for comorbidity, types of MD screening, and other moderators, severity of MD only affected deficits in processing speed, but not in other cognitive skills. This finding is consistent with previous studies and reviews (Landerl et al., 2004; Peng

& Fuchs, 2016), suggesting that the severity of MD, in general, does not affect the deficit profiles of MD, and MD may be a discrete construct. That said, the current study only focused on concurrent data. Future studies, especially those that focused on at-risk MD and persistent MD (Vukovic & Siegel, 2010), should consider longitudinal data to further investigate this issue. Fourth, the deficits in the high-level cognitive deficits are relatively independent of the deficits in low-level cognitive skills of MD. Compared to the deficits in low-level skills (except for processing speed), MD is more strongly and stably related to the deficits in high-level cognitive skills. Thus, it is likely that for individuals with MD, both their basic information processing system (e.g., numerical processing) and the complex information processing system (e.g., forming strategies and understanding conceptual knowledge) in mathematics are impaired.

Our findings also have implications for practice. Regarding the diagnosis of MD, our findings suggest the efficiency of MD diagnosis, especially in early grades, might be improved by conducting screenings on skills with salient cognitive deficits among MD. For example, in early grades (e.g., kindergarten and first grade) where traditional MD screening tests (e.g., calculations) may be insensitive (i.e., most children reach the floor on those tests), teachers/practitioners can use measures, such as processing speed, phonological processing, and attention ratings to help identify children at-risk for MD.

Interventions can be designed to compensate for the cognitive deficits of MD. For example, given that MD is related to distinct deficits in processing speed and working memory, especially in the numerical domain, instruction for MD should emphasize increasing numerical processing speed such as building fluency (e.g., improving arithmetic facts retrieval during calculations; using/selecting more efficient strategies during word problem-solving) to reduce working memory load in complex mathematic problems. This suggestion is also in line with the Load Reduction Instruction (LRI) theory (Martin, 2016). Researchers can design interventions that directly address these cognitive deficits among MD. Also, the cognitive interventions can be individualized for a specific type of MD. For example, whereas updating training may be crucial to remediate word-problem solving difficulties, phonological processing training may benefit MD identified with calculation difficulties most, especially those identified at a young age. Intervention materials can cover verbal, visuospatial, and numerical domains, but working memory training in the numerical domain seem most promising. With all being said, more research is needed to investigate whether and how direct cognitive training leads to and transfers to improved mathematics performance among MD.

References

Alloway, T. P., Gathercole, S. E., & Pickering, S. J. (2006). Verbal and visuospatial short-term and working memory in children: Are they separable? *Child Development*, *77*(6), 1698-1716. doi: 10.1111/j.1467-8624.2006.00968.x

*Andersson, U. (2008). Mathematical competencies in children with different types of learning difficulties. *Journal of Educational Psychology*, *100*(1), 48-66. doi: 10.1037/0022-0663.100.1.48

*Andersson, U. (2010). Skill development in different components of arithmetic and basic cognitive functions: Findings from a 3-year longitudinal study of children with different types of learning difficulties. *Journal of Educational Psychology*, *102*(1), 115-134. doi: 10.1037/a0016838

*Andersson, U., & Lyxell, B. (2007). Working memory deficit in children with mathematical difficulties: A general or specific deficit?. *Journal of Experimental Child Psychology*, *96*(3), 197-228.

*Ashkenazi, S., Rosenberg-Lee, M., Metcalfe, A. W., Swigart, A. G., & Menon, V. (2013). Visuo–spatial working memory is an important source of domain-general vulnerability in the development of arithmetic cognition. *Neuropsychologia*, *51*(11), 2305-2317. doi: 10.1016/j.neuropsychologia.2013.06.031

*Attout, L., & Majerus, S. (2015). Working memory deficits in developmental dyscalculia: The importance of serial order. *Child Neuropsychology*, *21*(4), 432-450. http://dx.doi.org/10.1080/09297049.2014.922170

Baddeley, A. (1986). Oxford psychology series, No. 11. Working memory.

*Badian, N. A. (1999). Persistent arithmetic, reading, or arithmetic and reading disability. *Annals of Dyslexia*, 45-70.

Berch, D. B., & Mazzocco, M. M. (2007). *Why Is Math So Hard for Some Children? The Nature and Origins of Mathematical Learning Difficulties and Disabilities*. Brookes Publishing Company. PO Box 10624, Baltimore, MD 21285.

Branum-Martin, L., Fletcher, J. M., & Stuebing, K. K. (2013). Classification and identification of reading and math disabilities: The special case of comorbidity. *Journal of Learning Disabilities*, *46*(6), 490–499. doi:10.1177/0022219412468767.

Rothstein, H. R., Sutton, A. J., & Borenstein, M. (Eds.). (2006). *Publication bias in meta-analysis: Prevention, assessment and adjustments*. John Wiley & Sons.

Bull, R., & Johnston, R. S. (1997). Children's arithmetical difficulties: Contributions from processing speed, item identification, and short-term memory. *Journal of Experimental Child Psychology*, *65*(1),1-24. https://doi.org/10.1006/jecp.1996.2358

Bull, R., & Lee, K. (2014). Executive functioning and mathematics achievement. *Child Development Perspectives*, *8*(1), 36-41.doi**:** 10.1111/cdep.12059

Bus, A. G., & Van IJzendoorn, M. H. (1999). Phonological processing and early reading: A meta-analysis of experimental training studies. *Journal of Educational Psychology*, *91*, 403-414. http://dx.doi.org/10.1037/0022-0663.91.3.403

*Busch, J., Schmidt, C., & Grube, D. (2015). Arithmetic Fact Retrieval. *Zeitschrift für Psychologie*. *223*(2), 110-119. https://doi.org/10.1027/2151-2604/a000209

Butterworth, B. (2005). The development of arithmetical abilities. *Journal of Child Psychology and Psychiatry*, *46*(1), 3-18.doi**:** 10.1111/j.1469-7610.2004.00374.x

*Censabella, S., & Noël, M. P. (2007). The inhibition capacities of children with mathematical disabilities. *Child Neuropsychology*, *14*(1), 1-20. http://dx.doi.org/10.1080/09297040601052318

*Chan, B. M. Y., & Ho, C. S. H. (2010). The cognitive profile of Chinese children with mathematics difficulties. *Journal of Experimental Child Psychology*, *107*(3), 260-279. https://doi.org/10.1016/j.jecp.2010.04.016

Cheng, Y. L., & Mix, K. S. (2014). Spatial training improves children's mathematics ability. *Journal of Cognition and Development*, *15*(1), 2-11. http://dx.doi.org/10.1080/15248372.2012.725186

*Cirino, P. T., Fletcher, J. M., Ewing-Cobbs, L., Barnes, M. A., & Fuchs, L. S. (2007). Cognitive arithmetic differences in learning difficulty groups and the role of behavioral inattention. *Learning Disabilities Research & Practice*, *22*(1), 25-35. doi: 10.1111/j.1540-5826.2007.00228.x

*Cirino, P. T., Fuchs, L. S., Elias, J. T., Powell, S. R., & Schumacher, R. F. (2015). Cognitive and mathematical profiles for different forms of learning difficulties. *Journal of Learning Disabilities*, *48*(2), 156-175. https://doi.org/10.1177/0022219413494239

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hilsdale, NJ: Lawrence Earlbaum Associates.

Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2013). *Applied multiple regression/correlation analysis for the behavioral sciences*. Routledge.

*D'Amico, A., & Passolunghi, M. C. (2009). Naming speed and effortful and automatic inhibition in children with arithmetic learning disabilities. *Learning and Individual Differences, 19*(2), 170-180. https://doi.org/10.1016/j.lindif.2009.01.001

Dehaene, S. (2011). *The number sense: How the mind creates mathematics*. OUP USA.

*De Weerdt, F., Desoete, A., & Roeyers, H. (2013). Working memory in children with reading disabilities and/or mathematical disabilities. *Journal of Learning Disabilities*, *46*(5), 461-472. https://doi.org/10.1177/0022219412455238

*De Weerdt, F., Desoete, A., & Roeyers, H. (2013b). Behavioral inhibition in children with learning disabilities. *Research in Developmental Disabilities*,*34*(6), 1998-2007. https://doi.org/10.1016/j.ridd.2013.02.020

*De Visscher, A., Szmalec, A., Van Der Linden, L., & Noël, M. P. (2015). Serial-order learning impairment and hypersensitivity-to-interference in dyscalculia. *Cognition*, *144*, 38-48. https://doi.org/10.1016/j.cognition.2015.07.007

*Donker, M., Kroesbergen, E., Slot, E., Van Viersen, S., & De Bree, E. (2016). Alphanumeric and non-alphanumeric Rapid Automatized Naming in children with reading and/or spelling difficulties and mathematical difficulties. *Learning and Individual Differences*, *47*, 80-87. https://doi.org/10.1016/j.lindif.2015.12.011

Edens, K., & Potter, E. (2008). How students “unpack” the structure of a word problem: Graphic representations and problem solving. *School Science and Mathematics*, *108*(5), 184-196. doi: 10.1111/j.1949-8594.2008.tb17827.x

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

Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science*, *11*(1), 19-23. https://doi.org/10.1111/1467-8721.00160

*Evans, M. (2008). Underlying cognitive processes in reading, math, and comorbid reading and math learning disabilities.

Friso-van den Bos, I., van der Ven, S. H., Kroesbergen, E. H., & van Luit, J. E. (2013). Working memory and mathematics in primary school children: A meta-analysis. *Educational Research Review*, *10*, 29-44. https://doi.org/10.1016/j.edurev.2013.05.003

Fuchs, D., Fuchs, L. S., & Compton, D. L. (2004). Identifying reading disabilities by responsiveness-to-instruction: Specifying measures and criteria. *Learning Disability Quarterly*, *27*(4), 216-227. https://doi.org/10.2307/1593674

Fuchs, L. S., Compton, D. L., Fuchs, D., Paulsen, K., Bryant, J. D., & Hamlett, C. L. (2005). The prevention, identification, and cognitive determinants of math difficulty. *Journal of Educational Psychology*, *97*(3), 493-513. http://dx.doi.org/10.1037/0022-0663.97.3.493

Fuchs, L. S., Fuchs, D., Compton, D. L., Bryant, J. D., Hamlett, C. L., & Seethaler, P. M. (2007). Mathematics screening and progress monitoring at first grade: Implications for responsiveness to intervention. *Exceptional Children, 73*(3), 311-330. https://doi.org/10.1177/001440290707300303

Fuchs, L. S., Fuchs, D., Compton, D. L., Powell, S. R., Seethaler, P. M., Capizzi, A. M., ... & Fletcher, J. M. (2006). The cognitive correlates of third-grade skill in arithmetic, algorithmic computation, and arithmetic word problems. *Journal of Educational Psychology*, *98*(1), 29-43. http://dx.doi.org/10.1037/0022-0663.98.1.29

Fuchs, L. S., Fuchs, D., & Prentice, K. (2004). Responsiveness to mathematical problem-solving instruction: Comparing students at risk of mathematics disability with and without risk of reading disability. *Journal of Learning Disabilities*, *37*(4), 293-306. https://doi.org/10.1177/00222194040370040201

*Fuchs, L. S., Fuchs, D., Stuebing, K., Fletcher, J. M., Hamlett, C. L., & Lambert, W. (2008). Problem solving and computational skill: Are they shared or distinct aspects of mathematical cognition?. *Journal of Educational Psychology*, *100*(1), 30-47. http://dx.doi.org/10.1037/0022-0663.100.1.30

Geary, D. C. (1993). Mathematical disabilities: cognitive, neuropsychological, and genetic components. *Psychological Bulletin*, *114*(2), 345. http://dx.doi.org/10.1037/0033-2909.114.2.345

Geary, D. C. (2005). Role of cognitive theory in the study of learning disability in mathematics. *Journal of Learning Disabilities*, *38*(4), 305-307. https://doi.org/10.1177/00222194050380040401

Geary, D. C. (2011). Cognitive predictors of achievement growth in mathematics: a 5-year longitudinal study. *Developmental Psychology*, *47*(6), 1539-1552.

*Geary, D. C., Hamson, C. O., & Hoard, M. K. (2000). Numerical and arithmetical cognition: A longitudinal study of process and concept deficits in children with learning disability. *Journal of Experimental Child Psychology*,*77*(3), 236-263. https://doi.org/10.1006/jecp.2000.2561

Geary, D. C., Hoard, M. K., Byrd-Craven, J., Nugent, L., & Numtee, C. (2007). Cognitive mechanisms underlying achievement deficits in children with mathematical learning disability. *Child Development*, *78*(4), 1343-1359.doi**:** 10.1111/j.1467-8624.2007.01069.x

*Geary, D. C., Hoard, M. K., & Hamson, C. O. (1999). Numerical and arithmetical cognition: Patterns of functions and deficits in children at risk for a mathematical disability. *Journal of Experimental Child Psychology*, *74*(3), 213-239. https://doi.org/10.1006/jecp.1999.2515

Gersten, R., Jordan, N. C., & Flojo, J. R. (2005). Early identification and interventions for students with mathematics difficulties. *Journal of Learning Disabilities*, *38*(4), 293-304. https://doi.org/10.1177/00222194050380040301

Gersten, R., Clarke, B., & Mazzocco, M. M. (2007). Historical and contemporary perspectives on mathematical learning disabilities. *Why is math so hard for some children*, 7-27.

Gilmore, C., & Cragg, L. (2014). Teachers' understanding of the role of executive functions in mathematics learning. *Mind, Brain, and Education*,*8*(3), 132-136.doi**:** 10.1111/mbe.12050

*Gold, A. B., Ewing-Cobbs, L., Cirino, P., Fuchs, L. S., Stuebing, K. K., & Fletcher, J. M. (2013). Cognitive and behavioral attention in children with math difficulties. *Child Neuropsychology*, *19*(4), 420-437. http://dx.doi.org/10.1080/09297049.2012.690371

*Gómez-Velázquez, F. R., Berumen, G., & González-Garrido, A. A. (2015). Comparisons of numerical magnitudes in children with different levels of mathematical achievement. An ERP study. *Brain Research*, *1627*, 189-200. https://doi.org/10.1016/j.brainres.2015.09.009

Grissom, R. J., & Kim, J. J. (2005). *Effect sizes for research: A broad practical approach*. Lawrence Erlbaum Associates Publishers.

Gross-Tsur, V., Manor, O., & Shalev, R. S. (1996). Developmental dyscalculia: Prevalence and demographic features. *Developmental Medicine & Child Neurology*, *38*(1), 25-33. doi**:** 10.1111/j.1469-8749.1996.tb15029.x

Halberda, J., & Feigenson, L. (2008). Developmental change in the acuity of the" Number Sense": The Approximate Number System in 3-, 4-, 5-, and 6-year-olds and adults. *Developmental Psychology*, *44*(5), 1457-1465. http://dx.doi.org/10.1037/a0012682

Halpern, D. F. (2004). A cognitive-process taxonomy for sex differences in cognitive abilities. *Current Directions in Psychological Science*, *13*(4), 135-139. https://doi.org/10.1111/j.0963-7214.2004.00292.x

Hecht, S. A., Torgesen, J. K., Wagner, R. K., & Rashotte, C. A. (2001). The relations between phonological processing abilities and emerging individual differences in mathematical computation skills: A longitudinal study from second to fifth grades. *Journal of Experimental Child Psychology*, *79*(2), 192-227. https://doi.org/10.1006/jecp.2000.2586

*Hecht, S. A., & Vagi, K. J. (2010). Sources of group and individual differences in emerging fraction skills. *Journal of Educational Psychology*,*102*(4), 843-859. http://dx.doi.org/10.1037/a0019824

Hedberg, E. C. (2011). Robumeta: Stata module to perform robust variance estimation in meta-regression with dependant effect size estimates [Stata ado file]. *Retrieved August*, *5*(2011), 2011-03.

Hedges, L. V., Tipton, E., & Johnson, M. C. (2010). Robust variance estimation in meta-regression with dependent effect size estimates. *Research Synthesis Methods*, *1*(1), 39-65. doi**:** 10.1002/jrsm.5

Hegarty, M., Mayer, R. E., & Monk, C. A. (1995). Comprehension of arithmetic word problems: A comparison of successful and unsuccessful problem solvers. *Journal of Educational Psychology*, *87*(1), 18-32. http://dx.doi.org/10.1037/0022-0663.87.1.18

Hill, C. J., Bloom, H. S., Black, A. R., & Lipsey, M. W. (2008). Empirical benchmarks for interpreting effect sizes in research. *Child Development Perspectives*, *2*(3), 172-177. DOI: 10.1111/j.1750-8606.2008.00061.x

Hitch, G. J., & McAuley, E. (1991). Working memory in children with specific arithmetical learning difficulties. *British Journal of Psychology*, *82*(3), 375-386. doi**:** 10.1111/j.2044-8295.1991.tb02406.x

Holloway, I. D., & Ansari, D. (2008). Domain-specific and domain-general changes in children's development of number comparison. *Developmental Science*, *11*(5), 644-649. doi**:** 10.1111/j.1467-7687.2008.00712.x

*Holm, M. E., Aunio, P., Björn, P. M., Klenberg, L., Korhonen, J., & Hannula, M. S. (2017). Behavioral Executive Functions Among Adolescents With Mathematics Difficulties. *Journal of Learning Disabilities*, 0022219417720684. https://doi.org/10.1177/0022219417720684

Holmes, J., Gathercole, S. E., & Dunning, D. L. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental Science*, *12*(4), F9-15. doi**:** 10.1111/j.1467-7687.2009.00848.x

*Hurks, P. P., & van Loosbroek, E. (2014). Time estimation deficits in childhood mathematics difficulties. *Journal of Learning Disabilities*, *47*(5), 450-461. https://doi.org/10.1177/0022219412468161

Jacob, R., & Parkinson, J. (2015). The potential for school-based interventions that target executive function to improve academic achievement: A review. *Review of Educational Research*, *85*, 512-552. https://doi.org/10.3102/0034654314561338

*Jolles, D., Ashkenazi, S., Kochalka, J., Evans, T., Richardson, J., Rosenberg-Lee, M., ... & Menon, V. (2016). Parietal hyper-connectivity, aberrant brain organization, and circuit-based biomarkers in children with mathematical disabilities. *Developmental Science*, *19*(4), 613-631. doi**:** 10.1111/desc.12399

Johnson, E. S., Humphrey, M., Mellard, D. F., Woods, K., & Swanson, H. L. (2010). Cognitive processing deficits and students with specific learning disabilities: A selective meta-analysis of the literature. *Learning Disability Quarterly*, *33*(1), 3-18. https://doi.org/10.1177/073194871003300101

Jordan, N. C., Hanich, L. B., & Kaplan, D. (2003). Arithmetic fact mastery in young children: A longitudinal investigation. *Journal of Experimental Child Psychology*, *85*(2), 103-119. https://doi.org/10.1016/S0022-0965(03)00032-8

Jordan, N. C., & Montani, T. O. (1997). Cognitive arithmetic and problem solving: A comparison of children with specific and general mathematics difficulties. *Journal of Learning Disabilities*, *30*(6), 624-634. https://doi.org/10.1177/002221949703000606

*Keeler, M. L., & Swanson, H. L. (2001). Does strategy knowledge influence working memory in children with mathematical disabilities?. *Journal of Learning Disabilities*, *34*(5), 418-434. https://doi.org/10.1177/002221940103400504

*Klesczewski, J., Brandenburg, J., Fischbach, A., Grube, D., Hasselhorn, M., & Büttner, G. (2015). Working Memory Functioning in Children With Poor Mathematical Skills. *Zeitschrift für Psychologie*. *223*(2), 83-92. https://doi.org/10.1027/2151-2604/a000206

Krajewski, K., & Schneider, W. (2009). Exploring the impact of phonological processing, visual–spatial working memory, and preschool quantity–number competencies on mathematics achievement in elementary school: Findings from a 3-year longitudinal study. *Journal of Experimental Child Psychology*,*103*(4), 516-531. https://doi.org/10.1016/j.jecp.2009.03.009

Kroesbergen, E. H., van't Noordende, J. E., & Kolkman, M. E. (2014). Training working memory in kindergarten children: Effects on working memory and early numeracy. *Child Neuropsychology*, *20*(1), 23-37. http://dx.doi.org/10.1080/09297049.2012.736483

*Kyttälä, M. (2008). Visuospatial working memory in adolescents with poor performance in mathematics: Variation depending on reading skills. *Educational Psychology*, *28*(3), 273-289. http://dx.doi.org/10.1080/01443410701532305

* Kyttälä, M., Aunio, P., & Hautamäki, J. (2010). Working memory resources in young children with mathematical difficulties. *Scandinavian Journal of Psychology*, *51*(1), 1-15. doi**:** 10.1111/j.1467-9450.2009.00736.x

*Landerl, K., Bevan, A., & Butterworth, B. (2004). Developmental dyscalculia and basic numerical capacities: A study of 8–9-year-old students. *Cognition*, *93*(2), 99-125. https://doi.org/10.1016/j.cognition.2003.11.004

*Landerl, K., Fussenegger, B., Moll, K., & Willburger, E. (2009). Dyslexia and dyscalculia: Two learning disorders with different cognitive profiles. *Journal of Experimental Child Psychology*, *103*(3), 309-324. https://doi.org/10.1016/j.jecp.2009.03.006

Linn, M. C., & Hyde, J. S. (1989). Gender, mathematics, and science. *Educational Researcher*, *18*(8), 17-27. https://doi.org/10.3102/0013189X018008017

Linn, M. C., & Petersen, A. C. (1985). Emergence and characterization of sex differences in spatial ability: A meta-analysis. *Child Development*, 1479-1498. doi:10.1111/j.1467-8624.1985.tb00213.x

*MacKinnon McQuarrie, M. A., Siegel, L. S., Perry, N. E., & Weinberg, J. (2014). Reactivity to stress and the cognitive components of math disability in grade 1 children. *Journal of Learning Disabilities*, *47*(4), 349-365. https://doi.org/10.1177/0022219412463436

Mark W.. Lipsey, & Wilson, D. B. (2001). *Practical meta-analysis* (Vol. 49). Thousand Oaks, CA: Sage publications.

Martin, A. J. (2016). *Using load reduction instruction (LRI) to boost motivation and engagement*. Leicester, UK: British Psychological Society

*Martin, R. B., Cirino, P. T., Barnes, M. A., Ewing-Cobbs, L., Fuchs, L. S., Stuebing, K. K., & Fletcher, J. M. (2013). Prediction and stability of mathematics skill and difficulty. *Journal of Learning Disabilities*, *46*(5), 428-443. https://doi.org/10.1177/0022219411436214

Mayes, S. D., Calhoun, S. L., & Crowell, E. W. (2000). Learning disabilities and ADHD: Overlapping spectrum disorders. *Journal of Learning Disabilities*, *33*(5), 417-424. https://doi.org/10.1177/002221940003300502

Mazzocco, M. M. (2005). Challenges in identifying target skills for math disability screening and intervention. *Journal of Learning Disabilities*, *38*(4), 318-323. https://doi.org/10.1177/00222194050380040701

Mazzocco, M. M., Singh Bhatia, N., & Lesniak-Karpiak, K. (2006). Visuospatial skills and their association with math performance in girls with fragile X or Turner syndrome. *Child Neuropsychology*, *12*(2), 87-110.http://dx.doi.org/10.1080/09297040500266951

*McCall, C. A. (2000). *Math computation difficulties in grade 7 and 8 students* (pp. 3622-3622). University of Toronto.

*McGlaughlin, S. M., Knoop, A. J., & Holliday, G. A. (2005). Differentiating students with mathematics difficulty in college: Mathematics disabilities vs. no diagnosis. *Learning Disability Quarterly*, *28*(3), 223-232. https://doi.org/10.2307/1593660

Melby-Lervåg, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental Psychology*, *49*(2), 270-291. doi: 10.1037/a0028228

Miyake, A., Emerson, M. J., & Friedman, N. P. (2000). Assessment of executive functions in clinical settings: Problems and recommendations. In Seminars in speech and language (Vol. 21, No. 02, pp. 0169-0183). Copyright© 2000 by Thieme Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA. Tel.:+ 1 (212) 584-4663. doi: 10.1055/s-2000-7563

Moll, K., Göbel, S. M., Gooch, D., Landerl, K., & Snowling, M. J. (2016). Cognitive risk factors for specific learning disorder: Processing speed, temporal processing, and working memory. *Journal of Learning Disabilities*, *49*(3), 272-281. https://doi.org/10.1177/0022219414547221

Morrison, A. B., & Chein, J. M. (2011). Does working memory training work? The promise and challenges of enhancing cognition by training working memory. *Psychonomic Bulletin & Review*, *18*(1), 46-60.

*Moura, R., Wood, G., Pinheiro-Chagas, P., Lonnemann, J., Krinzinger, H., Willmes, K., & Haase, V. G. (2013). Transcoding abilities in typical and atypical mathematics achievers: the role of working memory and procedural and lexical competencies. *Journal of Experimental Child Psychology*, *116*(3), 707-727. https://doi.org/10.1016/j.jecp.2013.07.008

Murphy, M. M., Mazzocco, M. M., Hanich, L. B., & Early, M. C. (2007). Cognitive characteristics of children with mathematics learning disability (MLD) vary as a function of the cutoff criterion used to define MLD. *Journal of Learning Disabilities*, *40*(5), 458-478. https://doi.org/10.1177/00222194070400050901

*Mussolin, C., Martin, R., & Schiltz, C. (2011). Relationships between number and space processing in adults with and without dyscalculia. *Acta Psychologica*, *138*(1), 193-203. https://doi.org/10.1016/j.actpsy.2011.06.004

Noël, M. P., Désert, M., Aubrun, A., & Seron, X. (2001). Involvement of short-term memory in complex mental calculation. *Memory & Cognition*, *29*(1), 34-42.

*Ostad, S. A. (2013). Private speech use in arithmetical calculation: Contributory role of phonological processing in children with and without mathematical difficulties. *Journal of Learning Disabilities*, *46*(4), 291-303. https://doi.org/10.1177/0022219411419013

*Ostad, S. A. (2015). Private speech use in arithmetical calculation: relationship with phonological memory skills in children with and without mathematical difficulties. *Annals of Dyslexia*, *65*(2), 103-119. doi:10.1007/s11881-015-0103-1

Palladino, P., Cornoldi, C., De Beni, R., & Pazzaglia, F. (2001). Working memory and updating processes in reading comprehension. *Memory & Cognition*, *29*(2), 344-354.

*Passolunghi, M. C. (2011). Cognitive and emotional factors in children with mathematical learning disabilities. *International Journal of Disability, Development and Education*, *58*(1), 61-73. http://dx.doi.org/10.1080/1034912X.2011.547351

Passolunghi, M. C., & Cornoldi, C. (2000). Working memory and cognitive abilities in children with specific difficulties in arithmetic word problem solving. *Advances in Learning and Behavioral Disabilities*, *14*, 155-178.

Passolunghi, M. C., Cornoldi, C., & De Liberto, S. (1999). Working memory and intrusions of irrelevant information in a group of specific poor problem solvers. *Memory & Cognition*, *27*(5), 779-790.

Passolunghi, M. C., & Pazzaglia, F. (2004). Individual differences in memory updating in relation to arithmetic problem solving. *Learning and Individual Differences*, *14*(4), 219-230. https://doi.org/10.1016/j.lindif.2004.03.001

*Passolunghi, M. C., & Siegel, L. S. (2001). Short-term memory, working memory, and inhibitory control in children with difficulties in arithmetic problem solving. *Journal of Experimental Child Psychology*, *80*(1), 44-57. https://doi.org/10.1006/jecp.2000.2626

*Passolunghi, M. C., & Siegel, L. S. (2004). Working memory and access to numerical information in children with disability in mathematics. *Journal of Experimental Child Psychology*, *88*(4), 348-367. https://doi.org/10.1016/j.jecp.2004.04.002

*Pauly, H., Linkersdörfer, J., Lindberg, S., Woerner, W., Hasselhorn, M., & Lonnemann, J. (2011). Domain-specific Rapid Automatized Naming deficits in children at risk for learning disabilities. *Journal of Neurolinguistics*, *24*(5), 602-610. https://doi.org/10.1016/j.jneuroling.2011.02.002

*Peng, P., Congying, S., Beilei, L., & Sha, T. (2012). Phonological storage and executive function deficits in children with mathematics difficulties. *Journal of Experimental Child Psychology*, *112*(4), 452-466. https://doi.org/10.1016/j.jecp.2012.04.004

Peng, P., & Fuchs, D. (2016). A meta-analysis of working memory deficits in children with learning difficulties: Is there a difference between verbal domain and numerical domain?. *Journal of Learning Disabilities*, *49*(1), 3-20. https://doi.org/10.1177/0022219414521667

Peng, P., & Miller, A. C. (2016). Does attention training work? A selective meta-analysis to explore the effects of attention training and moderators. *Learning and Individual Differences, 45*, 77-87. https://doi.org/10.1016/j.lindif.2015.11.012

Peng, P., Namkung, J., Barnes, M., & Sun, C. (2016). A Meta-Analysis of Mathematics and Working Memory: Moderating Effects of Working Memory Domain, Type of Mathematics Skill, and Sample Characteristics. *Journal of Educational Psychology*, *108*(4), 455-473. http://dx.doi.org/10.1037/edu0000079

*Peng, P., Sha, T., & Li, B. (2013). The deficit profile of working memory, inhibition, and updating in Chinese children with reading difficulties. *Learning and Individual Differences*, *25*, 111-117. https://doi.org/10.1016/j.lindif.2013.01.012

*Pinheiro-Chagas, P., Wood, G., Knops, A., Krinzinger, H., Lonnemann, J., Starling-Alves, I., ... & Haase, V. G. (2014). In how many ways is the approximate number system associated with exact calculation?. *PloS One*, *9*(11), e111155- e111155. https://doi.org/10.1371/journal.pone.0111155

Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience*, *13*(1), 25-42.doi: 10.1162/jocn.1989.1.2.153

*Raghubar, K., Cirino, P., Barnes, M., Ewing-Cobbs, L., Fletcher, J., & Fuchs, L. (2009). Errors in multi-digit arithmetic and behavioral inattention in children with math difficulties. *Journal of Learning Disabilities*, *42*(4), 356-371. DOI: https://doi.org/10.1177/0022219409335211

Raghubar, K. P., Barnes, M. A., & Hecht, S. A. (2010). Working memory and mathematics: A review of developmental, individual difference, and cognitive approaches. *Learning and Individual Differences*, *20*(2), 110-122. https://doi.org/10.1016/j.lindif.2009.10.005

*Reimann, G., Gut, J., Frischknecht, M. C., & Grob, A. (2013). Memory abilities in children with mathematical difficulties: Comorbid language difficulties matter. *Learning and Individual Differences*, *23*, 108-113. https://doi.org/10.1016/j.lindif.2012.10.017

Reuhkala, M. (2001). Mathematical skills in ninth-graders: Relationship with visuo-spatial abilities and working memory. *Educational Psychology*, *21*(4), 387-399. http://dx.doi.org/10.1080/01443410120090786

Rohde, T. E., & Thompson, L. A. (2007). Predicting academic achievement with cognitive ability. *Intelligence*, *35*(1), 83-92. https://doi.org/10.1016/j.intell.2006.05.004

*Rosselli, M., Matute, E., Pinto, N., & Ardila, A. (2006). Memory abilities in children with subtypes of dyscalculia. *Developmental Neuropsychology*, *30*(3), 801-818. http://dx.doi.org/10.1207/s15326942dn3003_3

*Rotzer, S., Loenneker, T., Kucian, K., Martin, E., Klaver, P., & Von Aster, M. (2009). Dysfunctional neural network of spatial working memory contributes to developmental dyscalculia. *Neuropsychologia*, *47*(13), 2859-2865. https://doi.org/10.1016/j.neuropsychologia.2009.06.009

*Rousselle, L., & Noël, M. P. (2007). Basic numerical skills in children with mathematics learning disabilities: A comparison of symbolic vs non-symbolic number magnitude processing. *Cognition*, *102*(3), 361-395. https://doi.org/10.1016/j.cognition.2006.01.005

Rovet, J., Szekely, C., & Hockenberry, M. N. (1994). Specific arithmetic calculation deficits in children with Turner syndrome. *Journal of Clinical and Experimental Neuropsychology*, *16*(6), 820-839. http://dx.doi.org/10.1080/01688639408402696

Ruff, H. A., & Lawson, K. R. (1990). Development of sustained, focused attention in young children during free play. *Developmental Psychology*, *26*(1), 85. http://dx.doi.org/10.1037/0012-1649.26.1.85

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review*, *103*(3), 403-428. http://dx.doi.org/10.1037/0033-295X.103.3.403

*Scarborough, H. S., & Parker, J. D. (2003). Children's Learning and Teachers' Expectations. *Annals of Dyslexia*, *53*.

*Schuchardt, K., Maehler, C., & Hasselhorn, M. (2008). Working memory deficits in children with specific learning disorders. *Journal of Learning Disabilities*, *41*(6), 514-523. https://doi.org/10.1177/0022219408317856

Shipstead, Z., Redick, T. S., & Engle, R. W. (2012). Is working memory training effective? *Psychological Bulletin*, *138*(4), 628-654. doi: 10.1037/a0027473

Siegel, L. S., & Ryan, E. B. (1989). The development of working memory in normally achieving and subtypes of learning disabled children. *Child Development*, 973-980.

Simmons, F. R., & Singleton, C. (2008). Do weak phonological representations impact on arithmetic development? A review of research into arithmetic and dyslexia. *Dyslexia*, *14*(2), 77-94.doi**:** 10.1002/dys.341

*Slot, E. M., van Viersen, S., de Bree, E. H., & Kroesbergen, E. H. (2016). Shared and Unique Risk Factors Underlying Mathematical Disability and Reading and Spelling Disability. *Frontiers in psychology*, *7*, 803-803. doi: 10.3389/fpsyg.2016.00803

*Swanson, H. L. (1994). The role of working memory and dynamic assessment in the classification of children with learning disabilities. *Learning Disabilities Research & Practice*, *9*(4), 190-202.

Swanson, H. L. (2006). Cross-sectional and incremental changes in working memory and mathematical problem solving. *Journal of Educational Psychology*, *98*(2), 265-281. http://dx.doi.org/10.1037/0022-0663.98.2.265

* Swanson, H. L. (2011). Dynamic testing, working memory, and reading comprehension growth in children with reading disabilities. *Journal of Learning Disabilities*, *44*(4), 358-371. https://doi.org/10.1177/0022219411407866

*Swanson, H. L. (2012). Cognitive profile of adolescents with math disabilities: Are the profiles different from those with reading disabilities? *Child Neuropsychology*, *18*(2), 125-143. http://dx.doi.org/10.1080/09297049.2011.589377

*Swanson, H. L. (2015). Cognitive strategy interventions improve word problem solving and working memory in children with math disabilities. *Frontiers in Psychology*, *6*, 1099-1099. doi: 10.3389/fpsyg.2015.01099

*Swanson, H. L., & Beebe-Frankenberger, M. (2004). The relationship between working memory and mathematical problem solving in children at risk and not at risk for serious math difficulties. *Journal of Educational Psychology*, *96*(3), 471-491. http://dx.doi.org/10.1037/0022-0663.96.3.471

Swanson, H. L., & Harris, K. R. (Eds.). (2013). *Handbook of learning disabilities*. Guilford Press.

Swanson, H. L., & Jerman, O. (2006). Math disabilities: A selective meta-analysis of the literature. *Review of Educational Research*, *76*(2), 249-274. https://doi.org/10.3102/00346543076002249

*Swanson, H. L., Jerman, O., & Zheng, X. (2008). Growth in working memory and mathematical problem solving in children at risk and not at risk for serious math difficulties. *Journal of Educational Psychology*, *100*(2), 343-379. http://dx.doi.org/10.1037/0022-0663.100.2.343

*Swanson, H. L., Lussier, C., & Orosco, M. (2013). Effects of cognitive strategy interventions and cognitive moderators on word problem solving in children at risk for problem solving difficulties. *Learning Disabilities Research & Practice*, *28*(4), 170-183.doi**:** 10.1111/ldrp.12019

*Swanson, H. L., Lussier, C. M., & Orosco, M. J. (2015). Cognitive strategies, working memory, and growth in word problem solving in children with math difficulties. *Journal of Learning Disabilities*, *48*(4), 339-358. https://doi.org/10.1177/0022219413498771

*Swanson, H. L., Orosco, M. J., & Lussier, C. M. (2014). The effects of mathematics strategy instruction for children with serious problem-solving difficulties. *Exceptional Children*, *80*(2), 149-168. https://doi.org/10.1177/001440291408000202

*Swanson, H. L., & Sachse-Lee, C. (2001). Mathematical problem solving and working memory in children with learning disabilities: Both executive and phonological processes are important. *Journal of Experimental Child Psychology*, *79*(3), 294-321. https://doi.org/10.1006/jecp.2000.2587

*Tobia, V., Fasola, A., Lupieri, A., & Marzocchi, G. M. (2016). Numerical magnitude representation in children with mathematical difficulties with or without reading difficulties. *Journal of Learning Disabilities*, *49*(2), 115-129. https://doi.org/10.1177/0022219414529335

Tolar, T. D., Lederberg, A. R., & Fletcher, J. M. (2009). A structural model of algebra achievement: computational fluency and spatial visualisation as mediators of the effect of working memory on algebra achievement. *Educational Psychology, 29*(2), 239-266. http://dx.doi.org/10.1080/01443410802708903

Toll, S. W., Van der Ven, S. H., Kroesbergen, E. H., & Van Luit, J. E. (2011). Executive functions as predictors of math learning disabilities. *Journal of Learning Disabilities*, *44*(6), 521-532. https://doi.org/10.1177/0022219410387302

*Toll, S. W., & Van Luit, J. E. (2014). Explaining numeracy development in weak performing kindergartners. *Journal of Experimental Child Psychology*, *124*, 97-111. https://doi.org/10.1016/j.jecp.2014.02.001

van der Sluis, S., de Jong, P. F., & van der Leij, A. (2004). Inhibition and shifting in children with learning deficits in arithmetic and reading. *Journal of Experimental Child Psychology*, *87*(3), 239-266. https://doi.org/10.1016/j.jecp.2003.12.002

*van der Sluis, S., van der Leij, A., & de Jong, P. F. (2005). Working memory in Dutch children with reading-and arithmetic-related LD. *Journal of Learning Disabilities*, *38*(3), 207-221. https://doi.org/10.1177/00222194050380030301

Venneri, A., Cornoldi, C., & Garuti, M. (2003). Arithmetic difficulties in children with visuospatial learning disability (VLD). *Child Neuropsychology*, *9*(3), 175-183.

*Vukovic, R. K. (2012). Mathematics difficulty with and without reading difficulty: Findings and implications from a four-year longitudinal study. *Exceptional children*, *78*(3), 280-300. https://doi.org/10.1177/001440291207800302

Vukovic, R. K., & Lesaux, N. K. (2013). The relationship between linguistic skills and arithmetic knowledge. *Learning and Individual Differences*, *23*, 87-91. https://doi.org/10.1016/j.lindif.2012.10.007

*Vukovic, R. K., & Siegel, L. S. (2010). Academic and cognitive characteristics of persistent mathematics difficulty from first through fourth grade. *Learning Disabilities Research & Practice*, *25*(1), 25-38. doi:10.1111/j.1540-5826.2009.00298.x

Wagner, R., Torgesen, J., & Rashotte, C. A. (1999). Test of word reading efficiency. *Austin, TX: Pro-Ed*.

Willcutt, E. G., Pennington, B. F., Olson, R. K., Chhabildas, N., & Hulslander, J. (2005). Neuropsychological analyses of comorbidity between reading disability and attention deficit hyperactivity disorder: In search of the common deficit. *Developmental Neuropsychology*, *27*(1), 35-78. http://dx.doi.org/10.1207/s15326942dn2701_3

*Willcutt, E. G., Petrill, S. A., Wu, S., Boada, R., DeFries, J. C., Olson, R. K., & Pennington, B. F. (2013). Comorbidity between reading disability and math disability: Concurrent psychopathology, functional impairment, and neuropsychological functioning. *Journal of Learning Disabilities*, *46*(6), 500-516. https://doi.org/10.1177/0022219413477476

*Wilson, K. M., & Swanson, H. L. (2001). Are mathematics disabilities due to a domain-general or a domain-specific working memory deficit? *Journal of Learning disabilities*, *34*(3), 237-248. https://doi.org/10.1177/002221940103400304

*Winegar, K. L. (2013). *Inhibition performance in children with math disabilities*. University of California, Riverside.

*Wu, S. S., Willcutt, E. G., Escovar, E., & Menon, V. (2014). Mathematics achievement and anxiety and their relation to internalizing and externalizing behaviors. *Journal of Learning Disabilities*, *47*(6), 503-514. https://doi.org/10.1177/0022219412473154

*Zafiris, C. M. (2010). *The Investigation of Patterns in Teacher Ratings of Executive Functioning in Children with Reading and Math Disabilities* (Doctoral dissertation, University of Northern Colorado).

Zentall, S. S. (1990). Fact-retrieval automatization and math problem solving by learning disabled, attention-disordered, and normal adolescents. *Journal of Educational Psychology*, *82*(4), 856-865. http://dx.doi.org/10.1037/0022-0663.82.4.856