ASHA American Speech-Language-Hearing Association

JSLHR

Review Article

Are Speech Sound Difficulties Risk Factors for Difficulties in Language and Reading Skills? A Systematic Review and Meta-Analysis

Line Walquist-Sørli,[a] Ømur Caglar-Ryeng,[a] Bjarte Furnes,[b] Trude Nergård-Nilssen,[a] Enrica Donolato,[c,d] and Monica Melby-Lervåg[a,c,d]

[a] Department of Education, UiT The Arctic University of Norway, Tromsø [b] Faculty of Psychology, University of Bergen, Norway [c] CREATE - Centre for Research on Equality in Education, University of Oslo, Norway [d] Department of Special Needs Education, University of Oslo, Norway

ARTICLE INFO

Article History:
Received March 13, 2024
Revision received June 1, 2024
Accepted September 24, 2024

Editor-in-Chief: Cara E. Stepp
Editor: Soo-Eun Chang

https://doi.org/10.1044/2024_JSLHR-24-00170

ABSTRACT

Background: Children with speech sound difficulties often require educational psychology services, yet systematic reviews examining the association between these difficulties and language or reading problems are lacking. This meta-analysis examines whether these children are at higher risk of language and reading difficulties compared to their peers.
Method: The study analyzed 290 effect sizes from cross-sectional and longitudinal studies that compared language and reading skills between children with speech sound difficulties and controls. Additionally, we evaluated 37 effect sizes from correlational studies in general populations to examine the relationship between speech sound skills and language or reading skills.
Results: Children with speech sound difficulties showed significant concurrent language (Hedges' g = –0.60) and reading (Hedges' g = –0.58) problems. Correlational studies also demonstrated a relationship between speech sound skills and language (r = .23) and reading (r = .23) skills. Phonological awareness and study quality were significant moderators. Longitudinal studies showed persistent or increasing group differences over time in language (Hedges' g = –0.85) and reading (Hedges' g = –0.50). These findings were consistent regardless of the severity or types of speech sound difficulties, nonverbal IQ, country, age, and publication year. However, a precision-effect test and the precision-effect estimate with standard errors analysis suggested a potential decrease in effect size due to publication bias from small sample sizes in primary studies.
Conclusion: Children with speech sound difficulties are at an increased risk of language and reading difficulties, emphasizing the need for broader language assessments and early interventions to mitigate future academic difficulties.
Supplemental Material: https://doi.org/10.23641/asha.27849828

Although most children learn to achieve intelligible speech during preschool age, speech errors, both articulation- and phonologically based errors, remain common problems for some children in kindergarten and the early school years. These errors might cause severe challenges for those affected, particularly in their interaction and communication with others. Such speech difficulties, typically referred to as speech sound difficulties, are also one of the most common reasons for requiring educational psychology services, speech and language therapy, and special education in young children (Bishop & Hayiou-Thomas, 2008; Eadie et al., 2015; Irwin et al., 2023; Zhang & Tomblin, 2000). Still, how speech sound difficulties relate to other language and later reading skills is far from understood. Numerous studies have examined whether children with speech sound difficulties are at an elevated risk of language and later reading difficulties, but no systematic reviews or meta-analyses on this topic currently exist. The present systematic review

Correspondence to Monica Melby-Lervåg: monica.melby-lervag@isp.uio.no. Enrica Donolato and Monica Melby-Lervåg share joint last authorship. ***Disclosure:*** *The authors have declared that no competing financial or nonfinancial interests existed at the time of publication.*

and meta-analysis aim to enhance our current understanding of whether children with speech sound difficulties in preschool age are at an increased risk of language and reading difficulties, both concurrently and longitudinally.

In terms of terminology, the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* defines speech sound disorder as persistent unintelligible speech that affects social, occupational, or academic performance, with symptoms starting in childhood and not attributable to other conditions (American Psychiatric Association, 2013). Thus, our focus here is on expressive speech sound skills. Subgrouping children with speech sound disorders has been proposed in different ways. Waring and Knight (2013) reviewed evidence supporting classification of subgroups and identified three common groups: an articulation-based subgroup, a phonological subgroup, and a motor planning/programming subgroup. The prevalence rates of speech sound disorders vary, but longitudinal studies indicate a rate of 3.4%–6.4% (Beitchman et al., 1986; Eadie et al., 2015; Shriberg et al., 1999; Wren et al., 2013). In this meta-analysis, we will concentrate on the articulation-based and phonological subgroups of speech sound difficulties and use the subgroups as moderates in the analysis. Although some studies specify the subgroup classification, many do not distinguish between these subgroups. Because the cutoff criteria across published studies with group comparisons vary and are often more lenient than those in the diagnostic manuals, we use the term *speech sound difficulties* rather than *speech sound disorders*.

Relationship Between Speech Sound Difficulties and Other Language Difficulties

Language abilities refer to the capacity to understand and produce utterances, encompassing both the receptive and expressive aspects of the semantic and syntactic domains of language. Another important aspect of language is phonological awareness skills, which involves the ability to manipulate speech sounds (Bishop & Snowling, 2004; Snowling & Hulme, 2021). Language ability is regarded as foundational to phonological awareness (Hjetland et al., 2019; Metsala & Walley, 2013; Snowling & Hulme, 2021), and phonological awareness, in turn, is a precursor for word reading skills. Still, the role of expressive speech sound skills in relation to other language skills and reading remains unclear. Studies exploring dimensionality suggest that speech sound skills are a distinct yet related construct relative to language ability and phonological awareness (Hayiou-Thomas et al., 2017; Pennington & Bishop, 2009). Thus, importantly, phonological awareness is a different but related skill compared with expressive speech sound skills.

Reports on whether individuals with speech sound difficulties also struggle with language abilities are inconsistent. They range from showing small differences in language measured with Peabody Picture Vocabulary Test (e.g., Apel & Henbest, 2020, Hedges' $g = -0.01$) to indicating significant difficulties using the same measure (e.g., Gerwin et al., 2021, Hedges' $g = -2.72$). A similar pattern has also been shown in studies of correlations between speech sound skills and language abilities in typically developing children (e.g., Burgoyne et al., 2019, $r = .13$; Durand et al., 2013, $r = .39$).

Relationship Between Speech Sound Skills and Reading Skills

The *simple view of reading* suggests that reading comprehension is a product of language abilities and decoding skills, with phonological awareness being a proximal determinant of decoding proficiency (Gough & Tunmer, 1986). Despite well-established research on the relation between phonological awareness problems and both reading difficulties and phonologically based speech sound difficulties, it remains unclear from prior studies how large the effect of phonological awareness problem is (e.g., Lewis et al., 2018, Hedges' $g = -0.09$; Caroll et al., 2014, $r = .29$; Overby, 2007, Hedges' $g = -1.64$; Moody, 2022, $r = .37$).

Regarding whether speech sound skills are contributing factors in determining future reading skills, the results also vary in prior research, particularly in the size of correlations between speech sound skills and later reading abilities (e.g., Burgoyne et al., 2019, $r = .16$; Durand et al., 2013, $r = .34$). A similar variation is observed in studies examining whether children with speech sound difficulties in preschool are more prone to reading difficulties later (e.g., Lewis et al., 2018, Hedges' $g = -0.07$; Lewis et al., 2019, Hedges' $g = -1.46$ [subsample persistence speech sound difficulties]).

Different explanations have been suggested for a putative relationship between preschool speech sound difficulties and later reading problems. One line of research suggests that the link between speech sound skills and reading is mediated by phonological awareness. Evidence supporting this comes from a study showing that phonological awareness fully mediates the relationship between speech sound difficulties and later reading (Burgoyne et al., 2019). This is in line with output phonology theory, which argues that deficits in speech *production* processes, output phonology, can lead to reading and spelling problems (Hulme & Snowling, 1992). This is also in line with further development of this theory suggesting that underlying problems with the quality of phonological representations might cause speech sound difficulties and problems

related to phonological awareness (Brosseau-Lapré & Roepke, 2020; Burgoyne et al., 2019). However, there is also evidence indicating that speech perception contributes to this issue. For instance, one study found that both speech perception and vocabulary were independent predictors of phonological awareness (Benway et al., 2021). Impaired speech production might also reflect issues in speech perception processes or input phonology. Finally, a rather different explanation suggests that the relationship between speech sound difficulties and later reading problems may stem from the possibility that problems with language could underpin both speech sound and phonological awareness skills, which, in turn, impacts reading skills (Peterson et al., 2009).

Possible Moderators of the Relationships Between Speech Sound and Language and Reading Skills

One factor that might explain why the different studies have reached different conclusions is that the severity of speech sound difficulties varies considerably across samples. Studies that use strict criteria to define speech sound difficulties might show larger group differences than those using more lenient criteria. The type of speech sound difficulties included in the sample could also play an important role in how these difficulties relate to language and reading skills (Dodd et al., 2024). Furthermore, factors such as children's age, nonverbal IQ variations, publication year, and country all play different roles in understanding the relationship between speech sound skills, language, and reading. For example, it has been suggested that younger children with speech sound difficulties show larger group differences compared to controls, particularly in language skills, because speech sound problems are more severe in younger children (Pennington & Bishop, 2009). Similarly, nonverbal IQ is positively associated with both language and reading skills (Peng et al., 2019) and could affect group differences if the children with speech sound difficulties and controls are poorly matched on nonverbal IQ. Publication year could be important since effects tend to be larger in seminal studies and then fade over time (Jennions & Møller, 2002). Country or region is also commonly included as a moderator, as results may vary based on factors such as lab environments or language backgrounds across different countries.

The Current Meta-Analysis

Summarizing the strengths of relationships and moderating factors related to speech sound difficulties is important both theoretically and clinically. Theoretically, clarifying the role of speech sound skills and their relationships with other language skills is crucial for enhancing our understanding of children's language development. This is particularly important in a field where numerous studies, often with limited sample sizes, yield divergent results. Clinically, understanding these relationships is important, as speech sound difficulties could potentially be markers for broader language difficulties and future reading problems. The clinical handling of speech sound difficulties likely varies by country. However, if these difficulties are dismissed as self-resolving, yet are clearly linked to later language and reading problems, they should not be ignored. Thus, results from this meta-analytic study could be highly valuable in determining who might need broader language assessment and subsequent support. Accordingly, this meta-analysis addresses the following research questions:

1. Do children with speech sound difficulties in preschool age exhibit weaker concurrent and later language and reading skills compared to controls? What factors moderate these differences?
2. Are preschool speech sound skills associated with concurrent and longitudinal language and reading skills in typical developing children? What factors moderate these relationships?
3. Are the results robust once publication bias is taken into account?

Method

This meta-analysis was preregistered in the Open Science Framework (OSF; https://osf.io/ypz4g/?view_only=51c1348d0e9841dfbe22be138c5b6cfe) and conducted in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Moher et al., 2009). The data set is also available in the OSF link above. Deviations from our protocol included expanding children's age range to 18 years. Furthermore, we lacked access to OpenGrey or Scopus, so these databases were not used in the literature search. Finally, we used the Joanna Briggs Institute's tools (Moola et al., 2017) to evaluate risk of bias instead of the Grading of Recommendations, Assessment, Development and Evaluation system (Aguayo-Albasini et al., 2014).

Literature Search

The literature search was conducted in May 2022 and updated in August 2023 across several databases, including MEDLINE, PsycINFO, ERIC, Web of Science, Linguistics and Language Behaviour Abstracts, Social Science, and ProQuest Dissertations & Theses Global. The search encompassed terms related to speech sound disorders and various reading and language difficulties, dating

back to 1992. Examples of search terms used include "speech sound disorders*" AND ("reading disorder*" OR "dyslexia*" OR "reading comprehension*" OR "developmental language disorder*" OR "reading disability*" OR "speech language impairment*" OR "DLD*" OR "SLI*"). The search was carried out by the first author with guidance from a retrieval expert at the University Library.

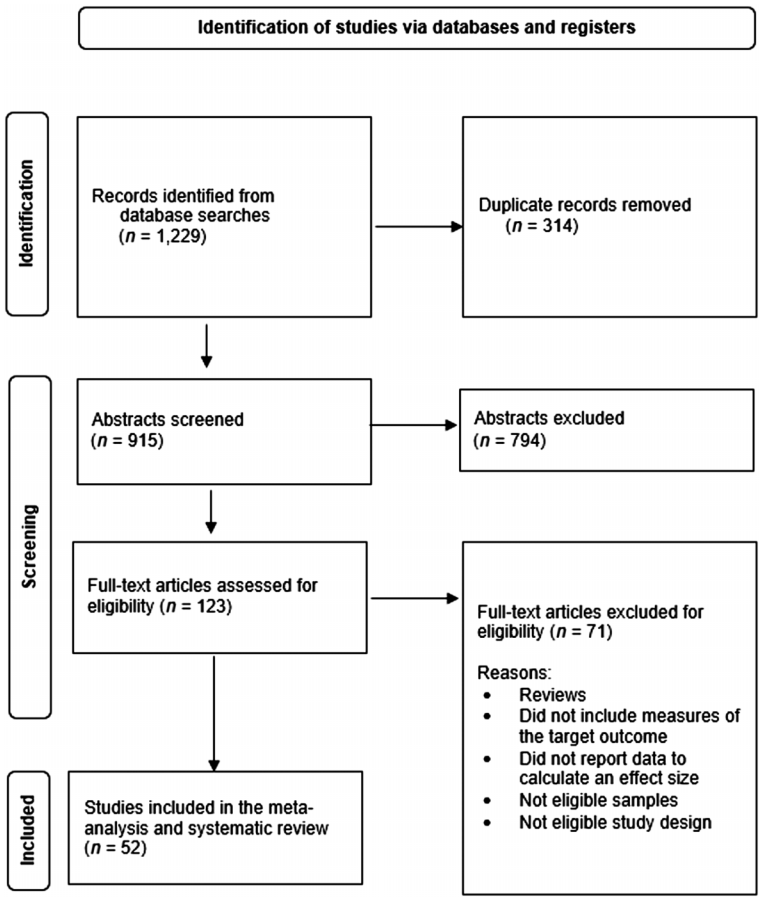
The electronic search yielded 915 records, after deduplication, which were screened in Rayyan software (Ouzzani et al., 2016). Twenty percent of the records were double-screened by the second author, achieving a Cohen's κ of .77 for interrater agreement. Discrepancies were discussed and resolved, resulting in 123 records for full-text screening. The selection process and final inclusion are detailed in Figure 1.

Inclusion and Exclusion Criteria

Group comparison studies had to include children aged 3–18 years with speech sound difficulties and evaluate their language abilities and/or reading skills either concurrently or longitudinally. Studies involving participants who stutter or have other conditions affecting speech sound pronunciation, such as cleft lip and/or palate, were excluded. Group comparison studies had to validate children's speech sound difficulties either by selecting children below a cutoff on standardized speech tests or through clinical assessment by an educational psychologist or a speech and language therapist in preschool. Speech sound skills had to be measured using standardized tests of articulation, speech sounds, vowels, oral motor skills, or word inconsistency. Controls had to be age-matched with the children with speech sound difficulties. Correlational studies had to involve typically developing children without speech sound difficulties. In both study designs, children had to be native speakers without hearing impairment; autism; intellectual disability; attention-deficit/hyperactivity disorder; or other neurodevelopmental, medical, or neurological conditions. Motor-planning/programming conditions were also excluded.

Eligible studies had to evaluate language or reading and reading-related skills. Language skills had to be measured with standardized tests of either expressive language,

Figure 1. Flow diagram of the literature search and study selection process.



receptive language, grammar and morphological skills, narrative skills, nonword repetition, or conversational language. Reading and reading-related skills had to be measured with standardized tests of letter knowledge, spelling, decoding, rapid automatized naming, or reading comprehension. If more than one measure was reported, effect sizes based on all indicators were reported. Both concurrent and longitudinal testing were included in the group comparison and correlational studies. The longitudinal samples had to assess speech sound skills in preschool and then language and reading at a subsequent stage. For the group comparison studies, we coded the group difference at the latest time point. As for the correlational studies, we coded the correlation between speech sound production at the initial assessment and language and reading skills at the final assessment.

Moderators

Types of speech sound difficulties. The types of speech sound difficulties in the samples were categorized as "articulation," "phonological," "both phonological and articulation," or "unknown." Articulation difficulties refer to distortions of the same sound in isolation, words, and sentences, which are typically consistent across imitation, elicitation, and spontaneous speech tasks (Waring & Knight, 2013). Phonological speech sound difficulties, on the other hand, can be classified as delayed typical phonological error patterns (phonological delay), more unusual, nondevelopmental error patterns (consistent phonological disorders), or inconsistency in speech production (inconsistent phonological disorder; Dodd, 2010). Despite the existence of several subtypes of phonological speech disorders, few studies differentiate between them. In this meta-analytic review, we have chosen to group all subtypes under the category of phonologically based speech difficulty.

Severity of speech sound difficulties. Hedges' *g* was calculated to evaluate the difference in speech sound skills between the children with speech sound difficulties and those in the control group.

Nonverbal IQ. Hedges' *g* was calculated to gauge how well the children with speech sound difficulties and control samples were matched on nonverbal IQ.

Phonological awareness. Hedges' *g* was calculated to assess the difference in phonological awareness skills (such as blending, segmenting, and elision) between the groups with speech sound difficulties and the controls.

Children's age. The mean ages of the children were coded.

Publication year. The publication years of the included studies were coded.

Country. Based on the sample location, the studies were classified as "Europe," the "United States," and "Other Countries."

Effect Sizes and Coding Procedure

For group comparison studies, the effect sizes for language and reading outcomes were calculated using means, standard deviations, and sample sizes for both the groups with speech sound difficulties and the control groups applying Hedges' *g* formula (Hedges & Olkin, 1985). A negative Hedges' *g* indicates that children with speech sound difficulties had greater language and reading problems compared to the controls. In correlational studies, correlation coefficients for the associations between speech sound skills and language or reading outcomes were coded, along with sample sizes. A higher correlation coefficient suggested a stronger association between speech sound skills and the outcomes of interest. To normalize the distribution of population effect sizes, correlations were transformed to Fisher's Z using R statistical software (Cohn & Becker, 2003). After analysis, the results were converted back to Pearson r for easier interpretation. All effect sizes were reported with 95% confidence intervals (CIs). If effect size data were missing, the study's author was contacted. Unreported moderators in the meta-analysis were coded as missing data. The second author double-coded a random sample of 20% of the studies. The intercoder agreement, calculated using Pearson r, was .99 for both comparison and correlational studies. Agreement percentages was 92.02% for comparison studies and 100% for correlational studies.

Study Quality Assessment

The quality of previous studies can impact our understanding of the relationships in question (Cuijpers et al., 2010). To evaluate the methodological quality of the studies included in this review, we used the Joanna Briggs Institute's (JBI) Checklist for Analytical Cross-Sectional Studies (Moola et al., 2017). The tool includes eight questions examining inclusion criteria, validity, reliability, and confounding factors. Each question was rated as "yes" (1 point), "no" (0 point), or "unclear" (0 point). The total score for each study was calculated and used to categorize risk of bias as low (> 70%), moderate (50%–69%), or high (< 49%).

Meta-Analytic Plan

Statistical analyses were run in R statistical software package (R Core Team, 2023) using the "metafor" (Viechtbauer, 2010) and "clubSandwich" (Pustejovsky, 2017) packages. To account for the complex structure of

dependencies in the data (i.e., multiple effects had correlated sampling errors within the same study and group comparison, and effects were nested within the studies), we performed correlated and hierarchical effects models (Pustejovsky & Tipton, 2022) within a multilevel modelling framework implemented in two steps. First, we specified the structure of variances using an imputed block-diagonal covariance matrix (Pustejovsky & Tipton, 2022), which assumed a constant correlation (p = .6) among the effect sizes clustered within the same study. Second, this variance structure was applied in a two-level random effects model, with random intercepts for both studies and individual effects. To answer our research questions, we planned different meta-regression models. We examined standardized differences in language versus reading, as well as correlations between speech sound skills and language versus reading, both concurrently and longitudinally, resulting in four meta-analyses. For these analyses, at least two studies were required (Valentine et al., 2010). Variability in effect sizes and heterogeneity were evaluated using the Q-statistic to test the null hypothesis that there is homogeneity in the underlying true effect size (either between or within studies), the I^2 to examine the proportion of observed variance that reflects true variation in effect sizes, and the τ to examine the standard deviation of the true effect sizes between studies and between effects (the last one referred to as ω; Borenstein et al., 2011).

Publication bias. We initially examined the contour-enhanced funnel plots, in which each effect size estimate was plotted against its standard error, with a reference line at 0 and contours indicating varying two-tailed p-value levels. To formally assess the funnel's symmetry, we used Egger's test (Egger et al., 1997), which involved a meta-regression in which the standard errors of the effect size estimates were used as predictors. When Egger's test is statistically significant, it indicates an asymmetry in the funnel plot and, therefore, publication bias. When this occurred, we employed the precision-effect test and the precision-effect estimate with standard errors (PET-PEESE; Stanley & Doucouliagos, 2014). The PET-PEESE analysis is a meta-regression method where the standard errors and variances of the effect size estimates are entered as predictors (Stanley & Doucouliagos, 2014). The intercepts in the PET-PEESE models provide an approximation for bias-adjusted estimates. Despite presenting some limitations, especially in the presence of large heterogeneity, the PET-PEESE method holds advantages as it accounts for small-study effects (Carter et al., 2019) and can accommodate multilevel structures of data (Rodgers & Pustejovsky, 2021). This method has the advantage of being easily implemented in multilevel structures of data but also some limitations. When the number of primary studies is small (i.e., $k < 20$), Egger's test has limited power to detect bias, and the PET-PEESE method tends to perform poorly (Stanley, 2017). Additionally, larger estimates in the PET-PEESE than the original effect sizes indicate heterogeneity rather than publication bias (Stanley, 2017).

Results

The results are based on the coding of 45 independent group comparisons, which include 200 effect sizes, and seven independent observational studies comprising 44 correlations that examine the relationship between speech sound skills and language and reading skills. The studies primarily involved English and American samples of children in preschool and primary school. As for study quality, the JBI rating indicated that while most studies had small samples, the risk of bias was low to moderate for both the group comparisons and correlational studies.

Comparison Group Studies

An overview of the group comparison studies used in the meta-analysis is provided in Supplemental Material S1.

Group Differences in Language Skills

Description of concurrent studies. A total of 37 studies examined group differences in language skills concurrently, published between 1993 and 2021. These studies included 901 children with speech sound difficulties and 1,343 controls (M_{age} = 69.19 months, SD = 16.38, range: 48.66–111.6 months; 57% boys). Some studies reported data on different samples of children with speech sound difficulties, including phonological difficulties only (17 samples), both phonological and articulation difficulties (eight samples), and articulation problems only (one sample). In 11 studies, the specifics of speech sound difficulties were unspecified. Most studies were conducted in the United States (30 studies), with a few in Europe (one study) and other countries (i.e., three studies from New Zealand, three studies from Australia, and one study from Canada). Only a minority of the studies were rated as high risk of bias (two studies), while the majority were rated as moderate (21 studies) or low risk of bias (14 studies).

The mean standardized group difference in language skills, calculated from 37 studies with 165 effects, indicated a negative and statistically significant estimate, g = −0.60, 95% CI [−0.72, −0.48]. This finding shows that children with speech sound difficulties had marked language difficulties compared to the controls. The true

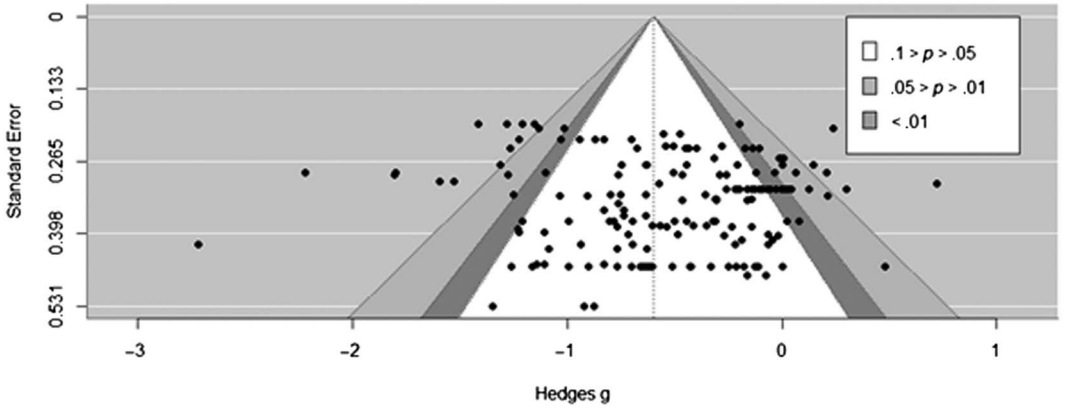
outcome was moderately heterogeneous (I^2 = 63%) and statistically significant, $Q(164) = 728.815$, $p < .001$ (τ_{study} = 0.12, ω = 0.39; see Supplemental Material S1 for the forest plot of single effect sizes across studies). Publication bias related to small samples was detected via Egger's test (B = −2.42, SE = 0.82, Z = −2.96, p = .003; see Figure 2). PET-PEESE analysis revealed that the bias-adjusted effect was positive and nonsignificant (PET: g = 0.18 [−0.35, 0.71], p = .512; PEESE: g = −0.10 [−0.40, 0.20], p = .358), indicating an overestimation of the initial estimate for the comparison group studies examining language skills concurrently due to small sample sizes in the primary studies.

Moderator analysis. Children's phonological awareness moderated the standardized group difference in language skills, indicating that samples with more severe phonological awareness problems also had more severe language problems (Q[1] = 10.833, p = .001, B = 0.44; 13 studies). In addition, nonverbal IQ was related to effect size, and the larger the discrepancy in nonverbal IQ between those with speech sound difficulties and the controls, the larger the difference in language skills (Q[1] = 8.701, p = .003, B = 0.56; 22 studies).

Children's severity of speech sound difficulties (Q[1] = 0.442, p = .506; 27 studies) and age (Q[1] = 0.188, p = .664; 37 studies) did not moderate the standardized group difference in language skills. The same pattern emerged for the types of speech sound difficulties (Q[1] = 0.878, p = .349; i.e., phonological awareness problems vs. phonological and articulation problems, with 17 vs. eight studies, respectively), as the estimates were comparable for phonological awareness problems, g = −0.64 [−0.81, −0.46], and for phonological and articulation problems, g = −0.48 [−0.73, −0.23]. Finally, publication year (Q[1] = 0.087, p = .768; 37 studies), country (Q[1] = 0.002, p = .963; comparing only the United States vs. other countries, 30 vs. six studies, respectively) and study quality (Q[1] = 1.145, p = .285; contrasting only moderate vs. low risk of bias, 21 vs. 14 studies, respectively) were not significant moderators. Estimates were similar for studies conducted in the United States, g = −0.60 [−0.72, −0.47], and other countries, g = −0.59 [−0.91, −0.27], and the same was the case for studies with a moderate, g = −0.53 [−0.69, −0.36], and low risk of bias, g = −0.66 [−0.84, −0.49].

Study description of longitudinal studies. There were six studies on group differences in language skills examined longitudinally published from 2008 to 2019. They evaluated 1,029 children with speech sound difficulties and 55,431 controls (M_{age} in months = 129.71, SD = 28.55, range: 102–179; 54% boys). Importantly, note that the mean age of the concurrent samples are 5.7 years. However, for the longitudinal studies, they were classified in preschool as with or without speech sound difficulties, but group differences for language and reading were coded at the last time point they were measured to look at persistency of the difficulties. Thus, the mean age in the longitudinal studies for the last time point was 11.75 years. The large number of children (59,015) in the control groups is due to a large-scale study conducted in Canada on kindergarten data from the early development instrument matched with standardized tests of reading and writing (and math) in Grade 3. Among these studies, the speech sound difficulties concerned phonological awareness problems only (one study) or were not specified as either phonological or articulation problems (five studies). Most of the longitudinal studies were from the United States (five studies; one study was from other countries, i.e., Canada). Overall, an equal number of studies was assessed as high, moderate, or low risk of bias (two studies for each category).

Figure 2. Funnel plot of all standardized group differences between children with speech sounds difficulties and controls in language skills examined concurrently. The black dots represent the effect sizes (Hedges' *g*). The *x*-axis represents the effect size, and the *y*-axis represents the standard error. The funnel is centered on the overall estimated effect size, and it indicates the width of the 95% confidence interval of an estimated effect as a function of its standard error.



The standardized mean group difference in language skills assessed longitudinally derived from six studies with 25 effects, showing a negative and statistically significant mean effect, $g = -0.85$, 95% CI [−1.21, −0.48], for example, children with speech sound difficulties had lower later language skills than the controls. The true outcome was heterogeneous ($I^2 = 98\%$) and statistically significant, $Q(24) = 4{,}855.870$, $p < .001$ ($\tau_{study} = 0.28$, $\omega = 0.61$; see forest plot with single effect sizes across studies in Supplemental Material S1). Publication bias and moderator analyses were not performed due to the limited number of studies available.

Group Differences in Reading and Reading-Related Skills

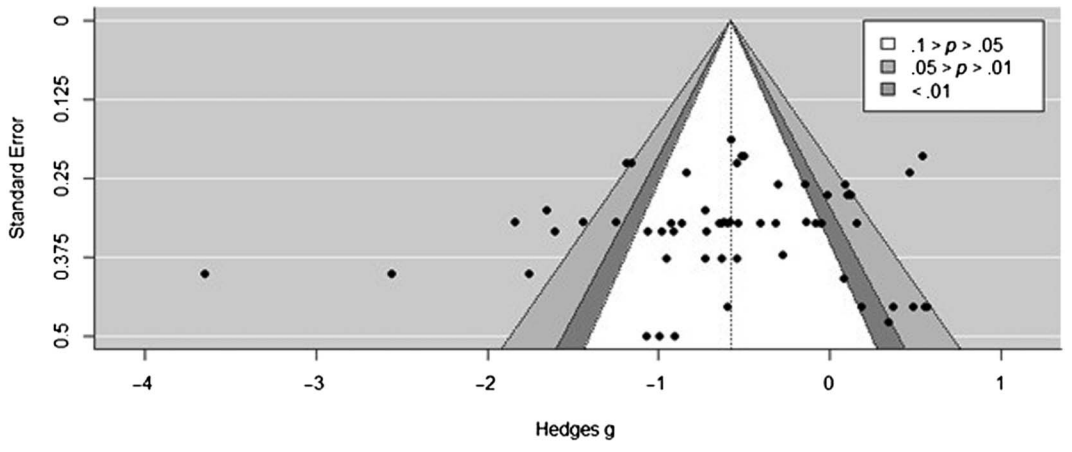
Study description of concurrent studies. Seventeen studies reported on group differences in reading outcomes examined concurrently. These studies, published between 1993 and 2021, included 493 children with speech sound difficulties and 874 controls (M_{age} in months = 80.18, $SD = 21.59$, range: 36.66–111.6; 61% boys). Some studies reported data on different samples of children with speech sound difficulties, including phonological difficulties only (six samples), both phonological and articulation difficulties (two samples), or unspecified conditions (nine samples). The majority of studies were conducted in the United States (12 studies), with a few others from Europe (one study) or other countries (i.e., two studies from New Zealand, one from Australia, and one from Canada). Most studies were rated as having a moderate risk of bias (nine studies) or low risk of bias (six studies), with only a few assessed as high risk of bias (two studies).

The mean standardized group difference in reading skills, calculated from 17 studies and 60 effects, revealed a negative and statistically significant effect, $g = -0.58$, 95% CI [−0.91, −0.25], indicating that children with speech sound difficulties had impaired reading skills compared to the controls. Heterogeneity was detected ($I^2 = 84\%$) and statistically significant, $Q(59) = 324.201$, $p < .001$ ($\tau_{study} = 0.58$, $\omega = 0.41$; see Figure S3 for the forest plot with single effect sizes across studies). Funnel plot asymmetry was detected via Egger's test in the concurrent studies ($B = -3.88$, $SE = 1.72$, $Z = -2.26$, $p = .024$; see Figure 3), with the PET-PEESE analysis showing that the bias-adjusted estimate was positive and nonsignificant (PET: $g = 0.69$ [−0.47, 1.84], $p = .243$; PEESE: $g = 0.10$ [−0.59, 0.80], $p = .768$).

Moderator analysis. Children's phonological awareness skills moderated the standardized group difference in reading skills, ($Q[1] = 18.924$, $p < .001$; 16 studies), with $B = 0.73$; that is, the more severe the problems in phonological awareness skills in those with speech sound difficulties, the greater the reading problems. Furthermore, study quality ($Q[1] = 4.797$, $p = .029$; comparing only moderate vs. a low risk of bias in nine vs. six studies, respectively) reached significance; studies with a moderate risk of bias showed lower estimates, $g = -0.31$ [−0.68, 0.07], compared with those rated as having a low risk of bias, $g = -1.01$ [−1.45, −0.56].

None of the other variables of interest, such as children's severity of speech sound difficulties ($Q[1] = 0.300$, $p = .584$; nine studies), nonverbal IQ ($Q[1] = 0.985$, $p = .321$; nine studies), age ($Q[1] = 2.956$, $p = .086$; 17 studies). and publication year ($Q[1] = 1.200$, $p = .273$; 16 studies), moderated the standardized group difference in reading skills. As only a few studies reported about the types of speech sound difficulties (phonological difficulties: six

Figure 3. Funnel plot of all standardized group differences between children with speech sounds difficulties and controls in reading skills examined concurrently. The black dots represent the effect sizes (Hedges' *g*). The *x*-axis represents the effect size, and the *y*-axis represents the standard error. The funnel is centered on the overall estimated effect size, and it indicates the width of the 95% confidence interval of an estimated effect as a function of its standard error.



studies; phonological and articulation difficulties: two studies), and most studies were conducted in the United States (i.e., 12, with only an additional four studies located in other countries), testing the moderator analysis for these variables was not possible.

Study description of longitudinal studies. With regard to group differences in reading skills examined longitudinally, there were eight studies published from 2008 to 2019 that examined 1,030 children with speech sound difficulties and 55,512 controls (M_{age} in months = 127.58, SD = 27.91, range: 96–179.4; 54% boys). Only a minority of the studies were on children defined with phonological difficulties only (one sample), and the others did not specify the type of speech sound difficulties (seven samples). The large majority of the studies were from the United States (seven studies; only one study was conducted in other countries, i.e., Canada). In addition, a few studies were assessed as high risk of bias (two studies) or moderate (three studies) or low risk of bias (three studies).

The longitudinal evaluation of standardized group differences in reading skills included eight studies with 40 effects. The mean estimate was still negative and statistically significant, $g = -0.50$, 95% CI [−0.77, −0.23], with children with speech sound difficulties having impaired later reading skills compared to the controls. The true outcome was heterogeneous (I^2 = 93%) and statistically significant, $Q(39) = 857.846$, $p < .001$ ($\tau_{study} = 0.29$, $\omega = 0.35$; see Figure S4 for the forest plot with single effect sizes across studies). Publication bias and moderator analyses were not carried out due to the small number of studies.

Correlational Studies

The characteristics of the correlational studies examined in the meta-analysis are reported in Supplemental Material S1. Due to the low number of correlational studies on our outcomes of interest, publication bias and moderator analyses were not performed.

Association Between Speech Sound Skills and Language Skills

Study description of concurrent studies. Four studies published between 2013 and 2020 examined the concurrent association between speech sound skills and language skills. These studies included 17,074 children (M_{age} in months = 57.22, SD = 14.62, range: 36–69; the percentage of boys was not available). All studies were conducted in Europe and rated as moderate (two studies) or low risk of bias (two studies).

The concurrent relationship between speech sound skills and language skills was examined with eight effects across four studies. The mean estimate was positive and statistically significant, r =.23, 95% CI [0.15, 0.29], indicating that higher speech sound skills were associated with better language skills, and conversely, poorer speech sound skills were associated with poorer language skills. Once again, heterogeneity was detected (I^2 = 83%) and statistically significant, $Q(7) = 37.448$, $p < .001$. The model did not estimate heterogeneity in the true effect size across studies, $\tau_{study} = 0.00$, but heterogeneity was detected between effect sizes within studies, $\omega = 0.09$ (see also Figure S5).

Study description of longitudinal studies. There was only one longitudinal study, published in 2019, that examined the association between speech sound skills and later language skills (Burgoyne et al., 2019). This study, conducted in Australia, included 552 children (M_{age} in months = 69.66, SD = 4.19; 48.15% of boys) and was assessed as having a moderate risk of bias. The study reported three statistically significant correlations between speech sound skills and language skills (expressive vocabulary r = .18, sentence structure r = .18, and listening comprehension r = .12).

Association Between Speech Sound Skills and Reading Skills

Study description of concurrent studies. Five studies published between 2009 and 2022 focused on the concurrent association between speech sound skills and reading outcomes. These studies included 1,015 children (M_{age} in months = 64.27, SD = 6.39, range: 55.2–71.5; 49% boys) from Europe and the United States (two and three studies, respectively). The studies were rated as having either a moderate risk of bias (two studies) or a low risk of bias (three studies).The relation between speech sound and reading skills was examined concurrently in 17 effects across five studies. The analysis revealed a positive and statistically significant effect, r =.21, 95% CI [0.15, 0.26], indicating that higher speech sound skills are associated with better reading skills. Heterogeneity was I^2 = 19% and not statistically significant, $Q(22) = 22.330$, $p = .133$. Once again, the model did not estimate heterogeneity in the true effect size across studies, $\tau_{study} = 0.00$, although heterogeneity was present between effect sizes within studies, ω = 0.03 (see Figure S6).

Study description of longitudinal studies. Three studies published between 2013 and 2020 examined the association between speech sound skills and later reading outcomes in 16,948 children (M_{age} in months = 95.22, SD = 25.18, range: 70–120; percentage of boys was not available). All studies were conducted in Europe and were rated as having moderate or low risk of bias (two and one study, respectively).

The longitudinal relationship between speech sound skills and later reading skills was examined in three studies

with nine effects. A positive and statistically significant effect was found, $r = .24$, 95% CI [0.14, 0.32], with higher speech sound skills associated with better later reading skills. The true outcome was heterogeneous ($I^2 = 84\%$) and statistically significant, $Q(8) = 35.514$, $p < .001$ ($\tau_{study} = 0.07$, $\omega = 0.05$; see Supplemental Material S1).

Discussion

Association Between Speech Sound Skills and Language Skills

This meta-analysis revealed that children with speech sound difficulties exhibit significantly lower language skills compared to controls in concurrent group comparison studies. The findings showed a group difference that was moderate to large. This result aligns with those in previous studies showing that children with speech sound difficulties often have concurrent language problems and vice versa (Lewis et al., 2015; Pennington & Bishop, 2009). Concurrent correlational studies of typically developing children also show a significant positive relationship between speech sound skills and language skills (Burgoyne et al., 2019; Durand et al., 2013). Furthermore, based on a conversion of Pearson *r* to Cohen's *d* (Poom & af Wåhlberg, 2022), the size of the relationship in typically developing children is comparable to the size of the difference that we found in studies with group comparisons of children with speech sound difficulties versus controls. Still, note that this conversion should be interpreted with some caution. Group comparison studies have a restriction of range since children are selected on poor language skills so the whole distribution is not covered, while observational studies is based on the full variation in an unselected group. Thus, converting effect sizes does not consider the design differences.

Findings also showed that phonological awareness is an important moderator, meaning that the more severe the problems in phonological awareness in those with speech sound difficulties, the greater the problems in language skills (or vice versa). This finding confirms a strong connection between phonological awareness problems and language skills in these children, supporting the theory that speech sound skills are interconnected with language abilities and phonology (Hayiou-Thomas et al., 2017; Pennington & Bishop, 2009). Although research has found that deficit in phonological awareness seems to appear in both speech sound difficulties and language difficulties, this meta-analysis is based on concurrent studies, and we can therefore only speculate about the causal relationship between phonological awareness, speech production ability, and language skills.

Importantly, the present results suggest that problems in language skills increase over time, as the longitudinal group differences (at the latest time point language skills were measured in the studies) in favor of the controls are significantly larger (with nonoverlapping CIs) than the concurrent group differences. However, there were insufficient studies to examine the mean correlation from longitudinal observational studies to support this finding.

Association Between Speech Sound Skills and Reading and Reading-Related Skills

Our meta-analysis from group comparison studies showed similar results when examining reading skills in children with and without speech sound difficulties. A moderate to large and statistically significant effect size indicated that reading skills in children with speech sound difficulties were impaired compared with the controls. This pattern was also observed in concurrent correlational studies of typically developing children, which showed a positive significant correlation between speech sound skills and reading skills. The size of the effect size in the correlational studies of typically developing children was around the size one would expect based on the group differences in children selected for speech sound difficulties.

Like language skills, children's phonological awareness skills moderated the standardized group differences in reading skills between children with and without speech sound difficulties; greater disparities in phonological awareness were associated with more severe reading problems. This finding supports prior research arguing that the relationship between speech sound skills and reading is mediated by phonological awareness skills (Burgoyne et al., 2019; Hulme & Snowling, 1992).

The longitudinal studies show that the reading problems in those with speech sound difficulties are persistent over time, with moderate group differences similar in size and not significantly different for those observed in concurrent studies. Unfortunately, there were insufficient studies to examine the mean correlation from longitudinal observational studies to support this result.

Still, after performing the PET-PEESE analysis, we found that the effect size estimate for the group differences in language and reading skills decreased, while for other subsets of outcomes, it was not possible to perform this analysis. This may be due to the presence of several studies with small sample sizes, leading to highly uncertain effect sizes (indicated by the large CIs; see the forest plots in Supplemental Material S1).

Limitations and Future Directions

A limitation of the current review is that there were too few studies to conduct finer grained analyses of

different types of reading and language skills. Furthermore, the design of the studies here was not suited to disentangle causality and to answer important questions about whether speech sound difficulties lead to phonological awareness problems and, in turn, reading problems, or whether language skills are confounders that underly speech sound difficulties, phonological awareness problems, and reading problems. To disentangle this, we need longitudinal studies of young children with frequent measurement points for all these skills to generate causal hypothesis that can be tested in experimental training studies.

Notably, PET-PEESE analysis showed that some of the results could be affected by publication bias due to the small sample sizes and very large CIs for the estimates of the single effect sizes and that findings should be interpreted with caution. This issue is common in meta-analyses involving clinical samples and highlights the need for future research to focus on recruiting larger samples.

Nevertheless, the current review provides valuable information of both theoretical and clinical importance. Theoretically, the study confirms a clear and consistent relationship between speech sound skills, phonological awareness skills, and language skills and that this, in turn, is also related to reading skills. Clinically, our findings suggest that preschool speech sound difficulties may signal wider language problems and a risk of language and reading difficulties. This information is important, as speech sound difficulties are easily noticeable, and based on our results, they should be considered risk indicators for those who need more in-depth language assessment and, in turn, early language interventions. This is important as the clinical management of children with speech sound difficulties likely varies between countries. Additionally, findings from this meta-analysis reveal a complex relationship between speech sound skills, phonological awareness skills, and language abilities, highlighting the need for further research.

Data Availability Statement

Preregistration, data, and scripts are available in the Open Science Framework (https://osf.io/ypz4g/?view_only=51c1348d0e9841dfbe22be138c5b6cfe). All authors confirm that they agree to share the raw data, any digital study materials and the analysis code, as appropriate.

Acknowledgments

This work was supported by the Research Council Norway Grant No. 327377 Centre for Research in Special Needs Education and Inclusion, awarded to Monica Melby-Lervåg and Bjarte Furnes; Grant No. 331640 CREATE, awarded to Monica Melby-Lervåg; and Read-Well Grant, awarded to Trude Nergård-Nilssen. All necessary approvals, including ethics, are in place for the proposed research.

References

Studies included in our analysis are marked with * in the reference list.

Aguayo-Albasini, J. L., Flores-Pastor, B., & Soria-Aledo, V. (2014). GRADE system: Classification of quality of evidence and strength of recommendation. *Cirugía Española (English Edition), 92*(2), 82–88. https://doi.org/10.1016/j.cireng.2013.08.002

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). https://doi.org/10.1176/appi.books.9780890425596

***Anthony, J. L., Williams, J. M., Aghara, R. G., Dunkelberger, M., Novak, B., & Mukherjee, A. D.** (2010). Assessment of individual differences in phonological representation. *Reading and Writing, 23*(8), 969–994. https://doi.org/10.1007/s11145-009-9185-7

***Apel, K., & Henbest, V. S.** (2020). Morphological awareness skills of second- and third-grade students with and without speech sound disorders. *Language, Speech, and Hearing Services in Schools, 51*(3), 603–616. https://doi.org/10.1044/2019_LSHSS-19-00045

***Apel, K., & Lawrence, J.** (2011). Contributions of morphological awareness skills to word-level reading and spelling in first-grade children with and without speech sound disorder. *Journal of Speech, Language, and Hearing Research, 54*(5), 1312–1327. https://doi.org/10.1044/1092-4388(2011/10-0115)

Beitchman, J. H., Nair, R., Clegg, M., Ferguson, B., & Patel, P. G. (1986). Prevalence of psychiatric disorders in children with speech and language disorders. *Journal of the American Academy for Child Psychiatry, 25*(4), 528–535. https://doi.org/10.1016/S0002-7138(10)60013-1

Benway, N. R., Garcia, K., Hitchcock, E., McAllister, T., Leece, M. C., Wang, Q., & Preston, J. L. (2021). Associations between speech perception, vocabulary, and phonological awareness skill in school-aged children with speech sound disorders. *Journal of Speech, Language, and Hearing Research, 64*(2), 452–463. https://doi.org/10.1044/2020_JSLHR-20-00356

Bishop, D. V. M., & Hayiou-Thomas, M. E. (2008). Heritability of specific language impairment depends on diagnostic criteria. *Genes, Brain and Behavior, 7*(3), 365–372. https://doi.org/10.1111/j.1601-183X.2007.00360.x

Bishop, D. V. M., & Snowling, M. J. (2004). Developmental dyslexia and specific language impairment: Same or different? *Psychological Bulletin, 130*(6), 858–886. https://doi.org/10.1037/0033-2909.130.6.858

Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2011). *Introduction to meta-analysis*. Wiley. https://doi.org/10.1002/9780470743386

***Brosseau-Lapré, F., & Kim, W. H.** (2020). Identification of foreign-accented words in preschoolers with and without speech sound disorders. *Journal of Speech, Language, and Hearing Research, 63*(5), 1340–1351. https://doi.org/10.1044/2020_JSLHR-19-00266

***Brosseau-Lapré, F., & Roepke, E.** (2019). Speech errors and phonological awareness in children ages 4 and 5 years with

and without speech sound disorder. *Journal of Speech, Language, and Hearing Research, 62*(9), 3276–3289. https://doi.org/10.1044/2019_JSLHR-S-17-0461

***Brosseau-Lapré, F., & Rvachew, S.** (2017). Underlying manifestations of developmental phonological disorders in French-speaking pre-schoolers. *Journal of Child Language, 44*(6), 1337–1361. https://doi.org/10.1017/S0305000916000556

***Brosseau-Lapré, F., & Schumaker, J.** (2020). Perception of correctly and incorrectly produced words in children with and without phonological speech sound disorders. *Journal of Speech, Language, and Hearing Research, 63*(12), 3961–3973. https://doi.org/10.1044/2020_JSLHR-20-00119

***Brosseau-Lapré, F., Schumaker, J., & Kluender, K. R.** (2020). Perception of medial consonants by children with and without speech and language disorders: A preliminary study. *American Journal of Speech-Language Pathology, 29*(2), 883–889. https://doi.org/10.1044/2020_AJSLP-19-00062

***Brosseau-Lapré, F., Schumaker, J., & Kluender, K. R.** (2020). Perception of medial consonants by preschoolers with and without speech sound disorders. *Journal of Speech, Language, and Hearing Research, 63*(11), 3600–3610. https://doi.org/10.1044/2020_JSLHR-20-00146

***Burgoyne, K., Lervag, A., Malone, S., & Hulme, C.** (2019). Speech difficulties at school entry are a significant risk factor for later reading difficulties. *Early Childhood Research Quarterly, 49,* 40–48. https://doi.org/10.1016/j.ecresq.2019.06.005

***Cabbage, K. L.** (2013). *Perceptual skills underlying phonological deficits in children: Evidence from behavioral and electrophysiological measures of speech perception* [Doctoral dissertation, University of Nebraska].

***Cabbage, K. L., Hogan, T. P., & Carell, T. D.** (2016). Speech perception differences in children with dyslexia and persistent speech delay. *Speech Communication, 82,* 14–25. https://doi.org/10.1016/j.specom.2016.05.002

***Carroll, J. M., Mundy, I. R., & Cunnigham, A. J.** (2014). The roles of family history of dyslexia, language, speech production and phonological processing in predicting literacy progress. *Developmental Science, 17*(5), 727–742. https://doi.org/10.1111/desc.12153

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

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

Cuijpers, P., van Straten, A., Bohlmeijer, E., Hollon, S. D., & Andersson, G. (2010). The effects of psychotherapy for adult depression are overestimated: A meta-analysis of study quality and effect size. *Psychological Medicine, 40*(2), 211–223. https://doi.org/10.1017/S0033291709006114

Dodd, B. (2010). *Differential diagnosis and treatment of children with speech sound disorders*. Whurr.

Dodd, B., Holm, A., & Crosbie, S. (2024). Clinical phonology and phonological assessment. In M.J. Ball, N. Müller, & E. Spencer (Eds.), *The handbook of clinical linguistics* (2nd ed., pp. 453–467).Wiley. https://doi.org/10.1002/9781119875949.ch32

***Durand, V. N., Loe, I. M., Yeatman, J. D., & Feldman, H. M.** (2013). Effects of early language, speech, and cognition on later reading: A mediation analysis. *Frontiers in Psychology, 4,* 586–586. https://doi.org/10.3389/fpsyg.2013.00586

Eadie, P., Morgan, A., Ukoumunne, O. C., Ttofari Eecen, K., Wake, M., & Reilly, S. (2015). Speech sound disorder at 4 years: Prevalence, comorbidities, and predictors in a community cohort of children. *Developmental Medicine & Child Neurology, 57*(6), Article 586. https://doi.org/10.1111/dmcn.12635

***Eaton, C. T.** (2014). *The role of executive functions in typical and atypical preschoolers' speech sound development* [Doctoral dissertation, University of Maryland].

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

***Ekelman, B. L.** (1993). *Examining the relationships among speech-language and reading skills in children with a history of speech-language or reading disorders* [Doctoral dissertation, Case Western Reserve University].

***Fox, A. M.** (2015). *Phonological awareness and executive function in children with speech sound impairment* [Doctoral dissertation, Arizona State University].

***Foy, J. G., & Mann, V. A.** (2012). Speech production deficits in early readers: Predictors of risk. *Reading and Writing, 25*(4), 799–830. https://doi.org/10.1007/s11145-011-9300-4

***Gerwin, K. L., Brosseau-Lapré, F., & Weber, C.** (2021). Event-related potentials elicited by phonetic errors differentiate children with speech sound disorder and typically developing peers. *Journal of Speech, Language, and Hearing Research, 64*(12), 4614–4630. https://doi.org/10.1044/2021_JSLHR-21-00203

***Gillon, G. T.** (2005). Facilitating phoneme awareness development in 3- and 4-year-old children with speech impairment. *Language, Speech, and Hearing Services in Schools, 36*(4), 308–324. https://doi.org/10.1044/0161-1461(2005/031)

***Gillon, G. T., McNeill, B., Denston, A., Scott, A., & Macfarlane, A.** (2020). Evidence-based class literacy instruction for children with speech and language difficulties. *Topics in Language Disorders, 40*(4), 357–374. https://doi.org/10.1097/TLD.0000000000000233

Gough, P. B., & Tunmer, W. E. (1986). Decoding, reading, and reading disability. *Remedial and Special Education, 7*(1), 6–10. https://doi.org/10.1177/074193258600700104

Hayiou-Thomas, M. E., Carroll, J. M., Leavett, R., Hulme, C., & Snowling, M. J. (2017). When does speech sound disorder matter for literacy? The role of disordered speech errors, co-occurring language impairment and family risk of dyslexia. *The Journal of Child Psychology and Psychiatry, 58*(2), 197–205. https://doi.org/10.1111/jcpp.12648

***Hearnshaw, S., Baker, E., & Munro, N.** (2018). The speech perception skills of children with and without speech sound disorder. *Journal of Communication Disorders, 71,* 61–71. https://doi.org/10.1016/j.jcomdis.2017.12.004

Hedges, L. V., & Olkin, I. (1985). *Statistical methods for meta-analysis*. Academic Press.

Hjetland, H. N., Lervåg, A., Lyster, S. A. H., Hagtvet, B. E., Hulme, C., & Melby-Lervåg, M. (2019). Pathways to reading comprehension: A longitudinal study from 4 to 9 years of age. *Journal of Educational Psychology, 111*(5), 751–763. https://doi.org/10.1037/edu0000321

***Holm, A., Ferrier, F., & Dodd, B.** (2008). Phonological awareness, reading accuracy and spelling ability of children with inconsistent phonological disorder. *International Journal of Language & Communication Disorders, 43*(3), 300–322. https://doi.org/10.1080/13682820701445032

Hulme, C., & Snowling, M. (1992). Deficits in output phonology: An explanation of reading failure? *Cognitive Neuropsychology, 9*(1), 47–72. https://doi.org/10.1080/02643299208252052

***Iuzzini, J.** (2012). *Inconsistency of speech in children with childhood apraxia of speech, phonological disorders, and typical speech* [Doctoral dissertation, Indiana University].

*Iuzzini-Seigel, J. (2019). Motor performance in children with childhood apraxia of speech and speech sound disorders. *Journal of Speech, Language, and Hearing Research, 62*(9), 3220–3233. https://doi.org/10.1044/2019_JSLHR-S-18-0380

*Iuzzini-Seigel, J. (2021). Procedural learning, grammar, and motor skills in children with childhood apraxia of speech, speech sound disorder and typically developing speech. *Journal of Speech, Language, and Hearing Research, 64*(4), 1081–1103. https://doi.org/10.1044/2020_JSLHR-20-00581

Irwin, V., Wang, K., Tezil, T., Zhang, J., Filbey, A., Jung, J., Bullock Mann, F., Dilig, R., & Parker, S. (2023). *Report on the condition of education 2023*. National Center for Education Statistics. https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2023144

*Janney, M. (2019). *Examining morphosyntactic skills in children with speech sound disorders* [Doctoral dissertation, Southeastern Louisiana University].

*Janus, M., Labonté, C., Kirkpatrick, R., Davies, S., & Duku, E. (2019). The impact of speech and language problems in kindergarten on academic learning and special education status in grade three. *International Journal of Speech-Language Pathology, 21*(1), 75–88. https://doi.org/10.1080/17549507.2017.1381164

Jennions, M. D., & Møller, A. P. (2002). Relationships fade with time: A meta-analysis of temporal trends in publication in ecology and evolution. *Proceedings of the Royal Society of London Series B: Biological Sciences, 269*(1486), 43–48. https://doi.org/10.1098/rspb.2001.1832

*Jin, F., Schjølberg, S., Eadie, P., Nes, R. B., & Røysamb, E. (2020). Preschool speech intelligibility and 8-year literacy: A moderated mediation analysis. *Journal of Speech, Language, and Hearing Research, 63*(10), 3380–3391. https://doi.org/10.1044/2020_JSLHR-19-00394

*Johnson, E. P., Pennington, B. F., Lowenstein, J. H., & Nittrouer, S. (2011). Sensitivity to structure in the speech signal by children with speech sound disorder and reading disability. *Journal of Communication Disorders, 44*(3), 294–314. https://doi.org/10.1016/j.jcomdis.2011.01.001

*Lewis, B. A., Avrich, A. A., Freebairn, L. A., Taylor, G. H., Iyengar, S. K. & Stein, C. M. (2011). Subtyping children with speech sound disorders by endophenotypes. *Topics in Language Disorders, 31*(2), 112–127. https://doi.org/10.1097/TLD.0b013e318217b5dd

*Lewis, B. A., Freebairn, L., Tag, J., Benchek, P., Morris, N. J., Iyengar, S. K., Taylor, H. G., & Stein, C. M. (2018). Heritability and longitudinal outcomes of spelling skills in individuals with histories of early speech and language disorders. *Learning and Individual Differences, 65,* 1–11. https://doi.org/10.1016/j.lindif.2018.05.001

*Lewis, B. A., Freebairn, L., Tag, J., Ciesla, A. A., Iyengar, S. K., Stein, C. M., & Taylor, H. G. (2015). Adolescent outcomes of children with early speech sound disorders with and without language impairment. *American Journal of Speech-Language Pathology, 24*(2), 150–163. https://doi.org/10.1044/2014_AJSLP-14-0075

*Lewis, B. A., Freebairn, L., Tag, J., Igo R. P., Jr., Ciesla, A., Iyengar, S. K., Stein, C. M., & Taylor, H. G. (2019). Differential long-term outcomes for individuals with histories of preschool speech sound disorders. *American Journal of Speech-Language Pathology, 28*(4), 1582–1596. https://doi.org/10.1044/2019_AJSLP-18-0247

*Mann, V. A., & Foy, J. G. (2007). Speech development patterns and phonological awareness in preschool children. *Annals of Dyslexia, 57*(1), 51–74. https://doi.org/10.1007/s11881-007-0002-1

Metsala, J. L., & Walley, A. C. (2013). Spoken vocabulary growth and the segmental restructuring of lexical representations: Precursors to phonemic awareness and early reading ability. In J. L. Metsala & L. C. Ehri (Eds.), *Word recognition in beginning literacy* (pp. 89–120). Routledge. https://doi.org/10.4324/9781410602718-9

*McNeil, B. C., Wolter, J., & Gillon, G. T. (2016). A comparison of the metalinguistic performance and spelling development of children with inconsistent speech sound disorder and their age-matched and reading-matched peers. *American Journal of Speech-Language Pathology, 26*(2), 456–468. https://doi.org/10.1044/2016_AJSLP-16-0085

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & the PRISMA Group. (2009). Reprint—Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA statement. *Physical Therapy, 89*(9), 873–880. https://doi.org/10.1093/ptj/89.9.873

*Moody, M. A. (2022). *Examining the relationships between the motoric, phonological awareness, rapid naming, and speech sound abilities of children* [Master's thesis, Valdosta State University].

Moola, S., Munn, Z., Tufanaru, C., Aromataris, E., Sears, K., Sfetcu, R., Currie, M., Lisy, K., Qureshi, R., Mattis, P., & Mu, P.-F. (2017). Chapter 7: Systematic reviews of etiology and risk. In E. Aromataris & Z. Munn (Eds.), *JBI reviewer's manual* (pp. 219–271). https://doi.org/10.46658/JBIMES-20-08

Ouzzani, M., Hammady, H., Fedorowicz, Z., & Elmagarmid, A. (2016). Rayyan—A web and mobile app for systematic reviews. *Systematic Reviews, 5*(1), Article 210. https://doi.org/10.1186/s13643-016-0384-4

*Overby, M. S. (2007). *Relationships among speech sound perception, speech sound production, and phonological spelling in second grade children* [Doctoral dissertation, University of Nebraska].

Peng, P., Wang, T., Wang, C., & Lin, X. (2019). A meta-analysis on the relation between fluid intelligence and reading/mathematics: Effects of tasks, age, and social economics status. *Psychological Bulletin, 145*(2), 189–236. https://doi.org/10.1037/bul0000182

Pennington, B. F., & Bishop, D. V. M. (2009). Relations among speech, language, and reading disorders. *Annual Review of Psychology, 60*(1), 283–306. https://doi.org/10.1146/annurev.psych.60.110707.163548

*Peter, B. (2006). *Multivariate characteristics and data-based disorder classification in children with speech disorders of unknown origin* [Doctoral dissertation, University of Washington].

*Peter, B. (2012). Oral and hand movement speeds are associated with expressive language ability in children with speech sound disorder. *Journal of Psycholonguistic Research, 41*(6), 455–474. https://doi.org/10.1007/s10936-012-9199-1

*Peterson, R. L., Pennington, B. F., Shriberg, L. D., & Boada, R. (2009). What influences literacy outcome in children with speech sound disorder? *Journal of Speech, Language, and Hearing Research, 52*(5), 1175–1188. https://doi.org/10.1044/1092-4388(2009/08-0024)

*Phinney, E. M. (2008). *Speech perception in speech sound disorder and reading disability* [Doctoral dissertation, University of Denver].

Poom, L., & af Wåhlberg, A. (2022). Accuracy of conversion formula for effect sizes: A Monte Carlo simulation. *Research Synthesis Methods, 13*(4), 508–519. https://doi.org/10.1002/jrsm.1560

Pustejovsky, J. E. (2017). *clubSandwich: Cluster-robust (sandwich) variance estimators with small-sample corrections*. https://cran.r-project.org/web/packages/clubSandwich/clubSandwich.pdf [PDF]

Pustejovsky, J. E., & Tipton, E. (2022). Meta-analysis with robust variance estimation: Expanding the range of working models. *Prevention Science, 23*(3), 425−438. https://doi.org/10.1007/s11121-021-01246-3

*Raitano, N. A., Pennington, B. F., Tunick, R. A., Boada, R., & Shriberg, L. D. (2004). Pre-literacy skills of subgroups of children with speech sound disorders. *The Journal of Child Psychology and Psychiatry, 45*(4), 821–835. https://doi.org/10.1111/j.1469-7610.2004.00275.x

R Core Team. (2023). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. https://www.r-project.org/

Rodgers, M. A., & Pustejovsky, J. E. (2021). Evaluating meta-analytic methods to detect selective reporting in the presence of dependent effect sizes. *Psychological Methods, 26*(2), 141–160. https://doi.org/10.1037/met0000300

*Roepke, E., Bower, K. E., Miller, C. A., & Brosseau-Lapré, F. (2020). The speech "Bamana": Using the syllable repetition task to identify underlying phonological deficits in children with speech and language impairments. *Journal of Speech, Language, and Hearing Research, 63*(7), 2229–2244. https://doi.org/10.1044/2020_JSLHR-20-00027

*Rvachew, S. (2007). Phonological processing and reading in children with speech sound disorders. *American Journal of Speech-Language Pathology, 16*(3), 260–270. https://doi.org/10.1044/1058-0360(2007/030)

*Schussler, K. F. (2012). *Working memory processes in children with and without persistent speech sound disorders* [Doctoral dissertation, University of Nebraska].

Shriberg, L. D., Tomblin, J. B., & McSweeny, J. L. (1999). Prevalence of speech delay in 6-year-old children and comorbidity with language impairment. *Journal of Speech, Language, and Hearing Research, 42*(6), 1461–1481. https://doi.org/10.1044/jslhr.4206.1461

*Skebo, C. M., Lewis, B., Freebairn, L. A., Tag, J., Ciesla, A. A., & Stein, C. M. (2013). Reading skills of students with speech sound disorders at three stages of literacy development. *Language, Speech, and Hearing Services in Schools, 44*(4), 360–373. https://doi.org/10.1044/0161-1461(2013/12-0015)

Snowling, M. J., & Hulme, C. (2021). Annual research review: Reading disorders revisited—The critical importance of oral language. *The Journal of Child Psychology and Psychiatry, 62*(5), 635–653. https://doi.org/10.1111/jcpp.13324

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 Synthesis Methods, 5*(1), 60–78. https://doi.org/10.1002/jrsm.1095

*Thomas, D., Lance, D. M., & Rainey, J. L. (2018). Phonemic awareness assessment of children with and without speech sound disorders: A comparison study. *Clinical Archives of Communication Disorders, 3*(2), 113–126. https://doi.org/10.21849/cacd.2018.00346

Valentine, J. C., Pigott, T. D., & Rothstein, H. R. (2010). How many studies do you need? A primer on statistical power for meta-analysis. *Journal of Educational and Behavioral Statistics, 35*(2), 215–247. https://doi.org/10.3102/1076998609346961

Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor package. *Journal of Statistical Software, 36*(3), 1–48. https://doi.org/10.18637/jss.v036.i03

*Vuolo, J., & Goffman, L. (2018). Language skill mediates the relationship between language load and articulatory variability in children with language and speech sound disorders. *Journal of Speech, Language, and Hearing Research, 61*(12), 3010–3022. https://doi.org/10.1044/2018_JSLHR-L-18-0055

*Waring, R., Eadie, P., Rickard Liow, S., & Dodd, B. (2017). Do children with phonological delay have phonological short-term and phonological working memory deficits? *Child Language Teaching and Therapy, 33*(1), 33–46. https://doi.org/10.1177/0265659016654955

Waring, R., & Knight, R. (2013). How should children with speech sound disorders be classified? A review and critical evaluation of current classification systems. *International Journal of Language and Communication Disorders, 48*(1), 25–40. https://doi.org/10.1111/j.1460-6984.2012.00195.x

*Wellman, R. L., Lewis, B. A., Freebairn, L. A., Avrich, A. A., Hansen, A. J., & Stein, C. M. (2011). Narrative ability of children with speech sound disorders and the prediction of later literacy skills. *Language, Speech, and Hearing Services in Schools, 42*(4), 561–579. https://doi.org/10.1044/0161-1461(2011/10-0038)

*Werfel, K. L., Al Otaiba, S., Kim, Y.-S., & Wanzek, J. (2021). Linguistic predictors of single-word spelling in first-grade students with speech and/or language impairments. *Remedial and Special Education, 42*(2), 118–128. https://doi.org/10.1177/0741932520918858

Wren, Y., McLeod, S., White, P., Miller, L. L., & Roulstone, S. (2013). Speech characteristics of 8-year-old children: Findings from a prospective population study. *Journal of Communication Disorders, 46*(1), 53–69. https://doi.org/10.1016/j.jcomdis.2012.08.008

Zhang, W., & Tomblin, J. B. (2000). The association of intervention receipt with speech-language profiles and social-demographic variables. *American Journal of Speech-Language Pathology, 9*(4), 345–357. https://doi.org/10.1044/1058-0360.0904.345