

Sex differences in language competence of 4-year-old children: Female advantages are mediated by phonological short-term memory

Benjamin P. Lange^{1,2*} and Eugen Zaretsky³

¹Department of Social Sciences, IU International University of Applied Sciences, Berlin, Germany,

²Department of Media Psychology, Julius Maximilian University of Wuerzburg, Wuerzburg, Germany and

³Department of Phoniatics and Paediatric Audiology, Marburg University Hospital, Marburg, Germany

*Corresponding author. Email: benjamin.lange@iu.org

Abstract

For some time now, psycholinguistic research has involved the study of sex differences in language development. Overall, girls seem to have an early advantage over boys, mainly in regard to vocabulary, which appears to decrease and, eventually, vanish with age. While there are numerous studies on sex differences in the acquisition of vocabulary as well as grammar, early sex differences in phonological short-term memory (PSTM) have been mostly neglected, or if research was conducted, it resulted in null findings, for the most part. In the present study, we examined sex differences in language competence (in a wide array of linguistic domains) of German children 4 years of age. Several tests were administered to assess articulation, vocabulary, grammar, speech comprehension, and, most importantly, PSTM (by means of the repetition of non-words and sentences). Girls performed better than boys in all domains, although some effect sizes were small. Most importantly, we found evidence for a female advantage in PSTM performance. Furthermore, mediation analyses revealed that the obtained sex differences in articulation, vocabulary, grammar, and comprehension were partially or fully mediated by (sex differences in) PSTM.

Keywords: gender differences; sex differences; language competence; language acquisition; language development; phonological short-term memory

Sex differences, that is, differences between individuals of different biological sex (sex assigned at birth), have been in the focus of empirical research for decades (e.g., Mealey, 2000). While some research investigating differences between female and male individuals employs the term “gender” for this categorization (for an overview, see Zell et al., 2015), other research uses the term “sex” in the sense of “biological sex” or “sex assigned at birth” (for an overview, see Mealey, 2000, pp. 11–25). The research at hand follows the second approach, thus investigating differences between biologically female and male individuals.

Among the research on sex differences, language-related sex differences have also been studied (e.g., Lange et al., 2014), including sex differences in language development (for an overview, see Wallentin, 2009). However, numerous sociodemographic/social variables apart from sex exist that may influence language development (e.g., Hoff, 2006; Tager-Flusberg, 2005; Zaretsky & Lange, 2017). For instance, socioeconomic status and levels of maternal and paternal education have been shown to be associated with children's language development (e.g., Dickinson & Porche, 2011; Letts et al., 2013; Noel et al., 2008; Taylor et al., 2013; Thomas et al., 2013; Zaretsky et al., 2014).

Despite an abundance of social factors that influence language development (apart from biological factors, e.g., prenatal testosterone; see Lange, 2015; Lutchmaya et al., 2001), the effects of biological sex on language development have attracted particular research interest (e.g., Lange et al., 2016; for an overview, see Wallentin, 2009). Such research on sex differences in early language development has consistently demonstrated that girls outperform boys, although this advantage (1) is mostly only slight and (2) diminishes or even vanishes with advancing age (e.g., Bauer et al., 2002; Beltz et al., 2013; Bornstein et al., 2004; Bouchard et al., 2009; Lange et al., 2016; Toivainen et al., 2017; for an overview, see Wallentin, 2009; see also Adani & Capanec, 2019).

The fact that sex differences in language development decrease with age also means that the more basic the linguistic domain is, the more likely such sex differences exist or the larger they are, respectively (for an overview, see Lange et al., 2016). For instance, findings in regard to a female advantage in vocabulary and the lexicon at an age of approximately eight months to two-and-a-half years are relatively robust (e.g., Berglund et al., 2005; Bleses et al., 2008; Bouchard et al., 2009; Feldman et al., 2000; Fenson et al., 1994; Lange et al., 2016). By contrast, sex differences in the acquisition of morpho-syntactic and grammatical features (at an older age) are minimal or even near zero, which means that girls outperform boys by only a very small margin, if at all, in this linguistic domain (e.g., Bornstein et al., 2004; Fenson et al., 1994; Hayiou-Thomas et al., 2012; for an overview, see Wallentin, 2009).

However, while the distinction between vocabulary and grammar is a well-established one and, furthermore, of practical relevance, there is one domain that lies beneath both vocabulary and grammar as it is far more basic, namely the phonetic/phonological domain (Baddeley, 2003). Within this domain, the so-called phonological short-term memory (PSTM) is crucial for processes involved in language comprehension and particularly production (Martin & Slevc, 2014).

The PSTM (sometimes used synonymously with the terms "verbal working memory" or "phonological loop"; cf. Baddeley, 2003; Szmalec et al., 2013) can be considered one part or subsystem of the working memory, according to the multi-component model of working memory developed by Baddeley and Hitch (1974; see Baddeley, 2003; for an overview, see also Collette et al., 2000; Szmalec et al., 2013; Van Dyke, 2012). The PSTM involves the ability to store and manipulate verbal and auditory/acoustic information in the short-term or working memory for a few seconds. Moreover, its function is to recognize and remember phonological elements and the order of their occurrence. Therefore, the PSTM is a short-term memory resource responsible for (temporarily) processing speech-based information.

The PSTM can be operationalized and, thus, assessed, by means of the performance in tasks on the repetition of (non-)words and sentences as well as digit spans (e.g., Euler et al., 2012; Grimm, 2001; Newbury et al., 2015; for an overview, see Baddeley, 2003; Conti-Ramsden & Durkin, 2012). Non-word repetition tasks are often utilized to measure PSTM in numerous language tests such as the German “Kindersprachscreening” (“Language screening for children”; KiSS; Holler-Zittlau et al., 2011). In repetition tasks, (non-)words and/or sentences are presented to the child orally. The child is then asked to repeat the respective linguistic material.

Such tasks usually result in substantial interindividual differences (i.e., children differ from one another in how well they are able to repeat the material), with a large portion of this phenotypic variance being attributable to genotypic variance (e.g., Kovas et al., 2005; Wadsworth et al., 1995; for an overview, see Stromswold, 2001).

A number of researchers have shown PSTM, quantified by performance in repetition tasks, to be a valid predictor of language development (e.g., Adlof & Patten, 2017; Bishop et al., 1996; Casserly & Pisoni, 2013; Chiat & Roy, 2013; Jackson et al., 2016; Nicolay & Poncelet, 2013; Rujas et al., 2017; Truong et al., 2016; for an overview, see Baddeley, 2003), particularly with respect to vocabulary skills (e.g., Baddeley et al., 1998; Gathercole & Baddeley, 1990a; Jones, 2016; Newbury et al., 2015; Nicolay & Poncelet, 2013; Roy & Chiat, 2004; Stokes & Klee, 2009; Torrington Eaton et al., 2015; see Baddeley, 2003; Szmalec et al., 2013, for an overview). Accordingly, poor PSTM abilities have been shown to be a correlate of language-related disorders such as specific language impairment and developmental language disorder (e.g., Befi-Lopes et al., 2010; D’Odorico et al., 2007; Estes et al., 2007; Gathercole & Baddeley, 1990b; Girbau & Schwartz, 2008; Gray, 2003; Montgomery et al., 2010; Pelczarski & Yaruss, 2016; Reichenbach et al., 2016; Truong et al., 2016; Willinger et al., 2017; for an overview, see Baddeley, 2003; Coady & Evans, 2008; Conti-Ramsden & Durkin, 2012).

Despite the importance of PSTM performance for language development, research that deliberately addressed sex differences in PSTM at preschool ages (1) is relatively scarce and (2) has resulted in null or, at best, inconsistent findings. So, there seems to be a noteworthy research gap that is surprising given the importance of PSTM for language development (for an overview, see Baddeley, 2003; Szmalec et al., 2013), while acknowledging the results of empirical research demonstrating an early female advantage in language development (e.g., Wallentin, 2009).

Regarding the scarcity of relevant research, it is, indeed, striking that most of the research on sex differences in language development cited above has not investigated PSTM or, if so, only as a side effect. An exception is the study by Lange et al. (2016), who identified an advantage for girls over boys at kindergarten age in the repetition of sentences of $d = 0.10$ and 0.16 , and in the repetition of non-words of d between 0.06 and 0.19 (depending on the instrument used and the sample). Likewise, a study by Martinelli (2013) found a slight advantage for girls over boys at kindergarten age in sentence repetition of $d = 0.20$ that, however, failed to reach statistical significance. According to these results, sex differences in PSTM are somewhere between zero and small. Other research has, indeed, found no sex differences in PSTM as measured by means of repetition tasks using (non-)words or sentences (Ardila et al., 2011; Ash et al., 2017; Burt et al., 1999; Chaney, 1992; Chiat & Roy, 2007; Kapalková et al., 2013; Kazemi & Saeednia, 2017; Radeborg et al., 2006;

Roy & Chiat, 2004; Topbaş et al., 2014; Tunmer et al., 1983). However, Krishnan et al. (2017) found a relatively large female advantage of $d = 0.73$ in non-word repetition in children aged 5–8 years (cf. Krishnan et al., 2017, p. 8). In regard to the inconsistency of research outcomes, it is notable that, apart from studies reporting a (slight) female advantage in PSTM and those reporting no sex differences, there is one study demonstrating a male advantage in non-word repetition (Farmani et al., 2018).

Therefore, according to the available data, whether sex differences in PSTM exist or not remains unclear. If they do, how large they are and what role they play in language development, in general, is not entirely clear. Thus, further research is needed to clarify this question. Furthermore, if sex differences in PSTM exist, they might be of interest for a consideration and even an explanation of sex differences in other linguistic domains. In the case of vocabulary, any word that is about to be acquired has to enter and pass the PSTM successfully (Newbury et al., 2015; Ramachandra et al., 2011). Furthermore, grammar acquisition might also depend to some degree on PSTM performance (Andrade & Baddeley, 2011). Thus, sex differences in PSTM might explain sex differences in, for instance, vocabulary size, at least to some extent. Hence, the current research had two objectives, namely (1) to check for sex differences in language competence in several linguistic domains and (2) to investigate the role of PSTM in explaining these differences.

Methods

The present research is based on a retrospective analysis of available data originally collected during the development of several German language screening tests.

Participants

Of the above-noted data, we used those that were complete for all children for the two tests employed (Mottier and KiSS.2). We used 4-year-old children only as they comprised the largest age group in the data. Also, one of the instruments that was used for the assessment of the children's language competence (i.e., KiSS; see below) is mainly designed for 4-year-old children. Written parental informed consent was available for all children tested.

In all, there were 224 participants (86 female, 138 male) aged 48–59 months ($M = 51.03$, $Mdn = 51$, $SD = 2.55$). Almost all were attending kindergarten. For 30 children, it was suspected that they might speak another language at home additionally apart from German. So, a small portion of the sample (up to appr. 13 %) might have comprised bilingual children. Testing took place in several towns and rural areas in the German states of Hesse and North Rhine-Westphalia. As our research consisted of the retrospective analysis of already available data, we did not conduct an a-priori power analysis.

We deemed it important to check for variables that were potentially confounded with sex. We, hence, investigated sex differences in several demographic and other variables that were mainly obtained by means of questionnaires for kindergarten teachers and/or the children's parents.

Girls ($M = 51.17$, $SD = 2.65$) and boys ($M = 50.93$, $SD = 2.49$) were of similar age in months ($t(222) = .683$, $p = .495$). Also, the length of kindergarten attendance (in months) was comparable for girls ($n = 36$; $M = 19.22$, $SD = 8.98$) and boys ($n = 93$; $M = 17.52$, $SD = 7.76$; $t(127) = 1.071$, $p = .286$), although not for all children, the relevant data were available (see ns and df in parentheses). We also checked for sex differences in parental educational level, which was assessed on a 5-point ordinal scale (1 = no school certificate, 2 = secondary school certificate, 3 = intermediate school-leaving certificate, 4 = Matura, 5 = high school). However, sample sizes were relatively low for the respective two variables (mother's educational level: $N = 11$, 8 boys; father's educational level: $N = 11$, 8 boys), which was simply due to the fact that obtaining such information mainly relied on the parents' willingness to fill out the respective questionnaire. Nonetheless, from the data that were available, it seemed that girls and boys were comparable with respect to both the mother's ($Mdns = 3$ and 4) and the father's educational level ($Mdns = 4$ and 3.75).

Next, we checked for sex differences in social (to be precise: playing) behavior. We obtained no sex difference for the respective variable, although the relevant data were again not available for all children (see ns and df in parentheses): Girls ($n = 38$; $M = 4.47$, $SD = 0.69$) and boys ($n = 99$; $M = 4.36$, $SD = 0.76$) had relatively similar values for the variable "The child likes to play with other children" that was rated by the kindergarten teachers on a 5-rating scale from 1 = never to 5 = always ($t(135) = 0.777$, $p = .439$).

Finally, we analyzed the available data from a non-verbal intelligence test (Coloured Progressive Matrices; Raven, 2009). No sex difference was found: Girls ($n = 60$) and boys ($n = 90$) were not significantly different from each other ($t(148) = 0.435$, $p = .664$).

As we included children who might have been bilingual instead of only monolingual, we also checked whether girls or boys were over-proportionately represented in the two groups of monolingual or bilingual children (or vice versa). The results showed that there was no such confounding of sex with language background ($\chi^2(1) = .243$, $p = .642$).

Language tests and questionnaires

The tests applied were the Mottier Test (Mottier, 1951) and the KiSS.2 (Holler-Zittlau et al., 2011). Language tests were administered in daycare centers in Hesse and North Rhine-Westphalia as part of a language screening program by trained linguistics students.

The Mottier Test (Mottier, 1951) examines PSTM (as well as speech-motoric coordination) and consists of non-words that the tested children are asked to repeat. We used the German version by Kiese-Himmel and Risse (2009). The KiSS.2 (Holler-Zittlau et al., 2011), sometimes referred to as MSSb (short, modified version of the Marburger Sprachscreening), tests pronunciation (i.e., phonetic and phonological skills) and, furthermore, includes a spontaneous speech task with two items. Children are asked to describe what they see in a picture, and, several items later, they are invited to ask the examiner anything they want with respect to the picture. In addition, it has tasks designed to assess vocabulary and grammar, and subtests

Table 1. Overview of the applied tests

Language domain	Task	No. of items	Score (Min/Max)
PSTM	Mottier (repetition of non-words)	30	0/30
PSTM	KiSS.2: repetition of non-words	4	0/12
PSTM	KiSS.2: repetition of sentences	2	0/15
Articulation	KiSS.2: articulation	13	0/15
Vocabulary	KiSS.2: vocabulary	9	0/23
Grammar	KiSS.2: grammar	13	0/30
Comprehension	KiSS.2: compreh.	3	0/8

Note. PSTM = phonological short-term memory; Comprehension = speech and language comprehension.

addressing speech and language comprehension. Finally, similar to the Mottier Test, the KiSS.2 examines PSTM by means of the repetition of non-words and sentences.

All wrong answers of the children were documented in standardized test batteries. All test sessions were audio recorded to control for possible documentation errors. In case of a low compliance or illness, test sessions were continued on another day. The Mottier Test does not require any special materials, which means that children were asked to repeat several non-words. KiSS.2 utilizes a large picture with objects and situations that are well-known to 4-year-old children (e.g., kindergarten, train, airplane, cars). Children are asked to answer questions such as “What is it?” and “What does it feel like?”. For more details on the procedure of KiSS testings, see, for instance, Zaretsky and Lange (2017) and Zaretsky et al. (2017). The psychometric properties of KiSS are reported to be very good (e.g., Neugebauer & Becker-Mrotzek, 2013). Table 1 provides an overview of the applied tests.

Statistical analyses

To investigate sex differences in several linguistic domains, *t* tests for independent samples were performed. Additionally, the effect size Cohen’s *d* was calculated based on mean values and standard deviations (Cohen, 1988). To counteract the problem of alpha-error inflation in multiple statistical comparisons, we applied the Bonferroni as well as the Bonferroni-Holm method (for an overview, see Abdi, 2007).

Simple mediation analyses were also performed to investigate whether sex predicts language competence and whether this direct path is mediated by PSTM performance (Mottier/KiSS.2 repetition of non-words/sentences). Specifically, the analyses were performed using the PROCESS macro by Hayes (2018) for SPSS Statistics, which uses ordinary least squares regression yielding unstandardized path coefficients for total, direct, and indirect effects. Bootstrapping ($m = 5,000$ bootstrap samples) together with heteroscedasticity-consistent standard errors was employed to compute confidence intervals and inferential statistics. With respect to the tested mediations, effects were considered statistically significant when the confidence interval did not include zero.

Results

Sex differences in language competence

Phonological short-term memory

Girls ($M = 17.09$, $SD = 6.05$) performed better than boys ($M = 14.72$, $SD = 5.91$) on the Mottier Test ($t(222) = 2.901$, $p = .004$, $d = 0.40$, 95% CI[0.13, 0.67]).

Next, we analyzed the KiSS.2 subtests starting with those that investigated PSTM by means of the repetition of non-words and sentences. Girls ($M = 2.69$, $SD = 1.20$) performed better than boys ($M = 2.07$, $SD = 1.39$) on the KiSS.2 non-word repetition task ($t(222) = 3.379$, $p = .001$, $d = 0.48$, 95% CI[0.21, 0.75]). Girls ($M = 11.80$, $SD = 3.75$) also performed better than boys ($M = 9.47$, $SD = 4.94$) in the KiSS.2 sentence repetition task ($t(213.529) = 3.996$, $p < .001$, $d = 0.54$, 95% CI[0.27, 0.82]). When investigating the sum score of the two above-noted KiSS.2 PSTM tasks, the advantage of girls ($M = 14.49$, $SD = 4.34$) over boys ($M = 11.54$, $SD = 5.89$) was—as could be expected given the results of each of the tests—again evident ($t(215.647) = 4.294$, $p < .001$, $d = 0.58$, (95% CI[0.30, 0.86])).

Articulation

Next, we analyzed the remaining KiSS.2 subtests starting with articulation. Girls ($M = 8.40$, $SD = 2.17$) performed better than boys ($M = 6.96$, $SD = 2.88$) in the subtest of articulation ($t(214.319) = 4.246$, $p < .001$, $d = 0.57$, 95% CI[0.29, 0.85]).

Vocabulary

Girls ($M = 7.16$, $SD = 1.65$) demonstrated a better performance than boys ($M = 6.11$, $SD = 2.14$) in the KiSS.2 subtest of vocabulary ($t(211.836) = 4.142$, $p < .001$, $d = 0.55$, 95% CI[0.27, 0.83]).

Grammar

The girls' ($M = 7.86$, $SD = 3.23$) performance was significantly better than that of the boys ($M = 6.78$, $SD = 3.54$) for the KiSS.2 subtest of grammar ($t(222) = 2.305$, $p = .022$, $d = 0.32$, 95% CI[0.05, 0.59]), although this sex difference was relatively small (see CI).

Speech and language comprehension

Girls ($M = 2.56$, $SD = 0.57$) showed better performance than boys ($M = 2.28$, $SD = 0.89$) on the KiSS.2 subtest of speech and language comprehension ($t(221.936) = 2.899$, $p = .004$, $d = 0.38$, 95% CI[0.11, 0.65]).

In summary, it became evident that girls performed better than boys in all domains, although some differences were relatively small. Also, after Bonferroni correction, the sex difference in grammar was not statistically significant anymore (adjusted p value = .176), whereas after applying the Bonferroni-Holm method, all sex differences remained statistically significant. Figure 1 illustrates a visual summary of the findings for all language variables mentioned thus far.

When taking the confidence intervals into consideration, five of the eight sex differences (i.e., repetition of non-words, repetition of sentences, repetition of

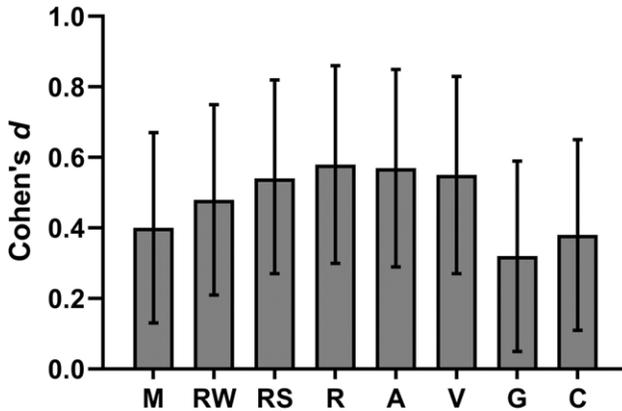


Figure 1. Sex differences in different language domains/tests.

Notes: Positive values indicate a female advantage. Error bars show the 95% CI of the effect size Cohen's *d*. Abbreviations on the x-axis: M = Mottier Test; KiSS.2: RW = repetition of non-words, RS = repetition of sentences, R = repetition of non-words and sentences, A = articulation, V = vocabulary, G = grammar, C = speech and language comprehension.

non-words and sentences, articulation, and vocabulary from the KiSS.2) were at least small ($d > 0.20$; cf. Cohen, 1988) with a probability of 95% and, thus, larger than zero.

The mediation of sex differences in language competence by PSTM

Articulation

Following the structure established above, we started with articulation. First, we conducted the analysis using the score of the Mottier Test performance as the mediator. As could be expected, a total effect of sex on performance in articulation was observed ($B = 1.439, p < .001$). After entering the mediator into the model, sex predicted the mediator significantly ($B = 2.376, p = .005$), which, in turn, predicted articulation ($B = 0.211, p < .001$). Furthermore, we found that the relationship between sex and performance in articulation was partially mediated by the Mottier Test performance, as the direct effect ($B = 0.937, p = .003$) was smaller than the total effect. Also, the indirect effect was significant ($ab = 0.502, 95\% \text{ CI}[0.167, 0.876]$).

Next, we conducted the analysis using the performance on the KiSS.2 subtest of non-word repetition as the mediator. Sex predicted the mediator significantly ($B = 0.614, p < .001$), which, in turn, predicted performance in articulation ($B = 0.882, p < .001$). Furthermore, we found that the relationship between sex and articulation was partially mediated by performance on the KiSS.2 non-word repetition task, as the direct effect ($B = 0.898, p = .005$) was smaller than the total effect. Again, the indirect effect was also significant ($ab = 0.541, 95\% \text{ CI}[0.216, 0.909]$).

Finally, we conducted the analysis using the performance on the KiSS.2 subtest of sentence repetition as the mediator. Sex predicted the mediator significantly ($B = 2.331, p < .001$), which, in turn, predicted performance on articulation

($B = 0.296$, $p < .001$). We found that the relationship between sex and articulation was partially mediated by performance in the KiSS.2 sentence repetition task, as the direct effect ($B = 0.748$, $p = .015$) was smaller than the total effect. The indirect effect was again significant ($ab = 0.691$, 95% CI[0.333, 1.093]).

Thus, we found evidence for a (partial) mediation of sex differences in articulation by (sex differences in) PSTM.

Vocabulary

The next language domain investigated was vocabulary. Again, the Mottier Test performance was chosen first as the mediator. As could be expected, a total effect of sex on vocabulary performance was observed ($B = 1.054$, $p < .001$). Sex predicted the mediator, which in turn predicted vocabulary performance ($B = 0.126$, $p < .001$). Furthermore, we found that the relationship between sex and vocabulary was partially mediated by Mottier Test performance, as the direct effect ($B = 0.754$, $p = .002$) was smaller than the total effect. Again, we found a significant indirect effect ($ab = 0.300$, 95% CI[0.093, 0.549]).

Next, we conducted the analysis using the performance on the KiSS.2 subtest of non-word repetition as the mediator. Sex predicted the mediator, which, in turn, predicted vocabulary performance ($B = 0.591$, $p < .001$). Furthermore, we found that the relationship between sex and vocabulary was partially mediated by performance in the KiSS.2 non-word repetition task, as the direct effect ($B = 0.691$, $p = .006$) was smaller than the total effect. Again, the indirect effect was significant ($ab = 0.363$, 95% CI[0.149, 0.630]).

Finally, we conducted the analysis using the performance on the KiSS.2 subtest of sentence repetition as the mediator. Sex predicted the mediator, which, in turn, predicted vocabulary performance ($B = 0.234$, $p < .001$). Furthermore, we found that the relationship between sex and vocabulary was partially mediated by performance on the KiSS.2 sentence repetition task, as the direct effect ($B = 0.508$, $p = .032$) was smaller than the total effect. Again, the indirect effect was significant ($ab = 0.547$, 95% CI[0.263, 0.885]).

To summarize the results of the mediational analyses thus far, sex differences both in articulation and in vocabulary were partially mediated by PSTM measures. Figure 2 provides a visual summary for both domains.

Grammar

The next language domain investigated was grammar. Again, the Mottier Test performance was chosen first as the mediator. As could be expected, a total effect of sex on grammar performance was observed ($B = 1.085$, $p = .020$). Sex predicted the mediator, which, in turn, predicted performance on grammar ($B = 0.224$, $p < .001$). Furthermore, we found that the relationship between sex and grammar was fully mediated by the Mottier Test performance as the direct effect ($B = 0.554$, $p = .193$) was not significant, whereas the indirect effect was ($ab = 0.531$, 95% CI[0.156, 0.941]).

Next, we conducted the analysis using performance on the KiSS.2 subtest of non-word repetition as the mediator. Sex predicted the mediator, which in turn predicted performance in grammar ($B = 1.136$, $p < .001$). Furthermore, we found that the

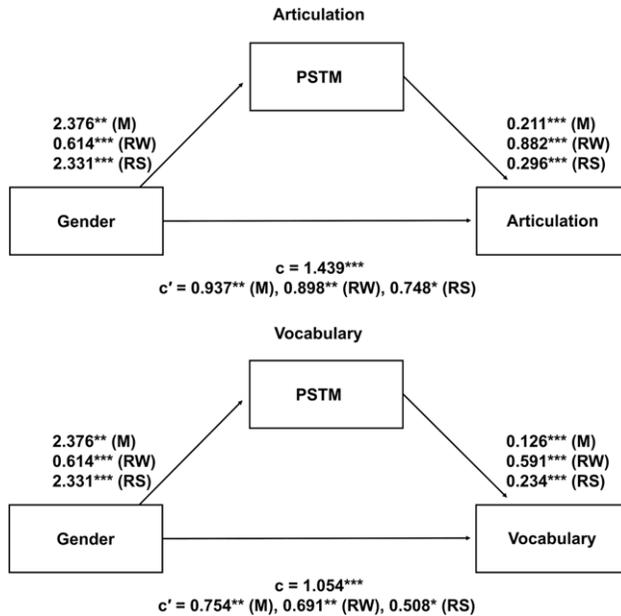


Figure 2. Partial mediations between sex and performance in articulation (top) and vocabulary (bottom) by measures of phonological short-term memory (Mottier Test, repetition of non-words, repetition of sentences).

Notes: * $p < .05$, ** $p < .01$, *** $p < .001$. Abbreviations: PSTM = phonological short-term memory, M = Mottier Test; KiSS.2: RW = repetition of non-words, RS = repetition of sentences.

relationship between sex and grammar performance was fully mediated by performance in the KiSS.2 non-word repetition task because the direct effect ($B = 0.388$, $p = .376$) did not reach significance, while the indirect effect did ($ab = 0.697$, 95% CI[0.278, 1.167]).

Finally, we conducted the analysis using performance on the KiSS.2 subtest of sentence repetition as the mediator. Sex predicted the mediator, which, in turn, predicted grammar performance ($B = 0.481$, $p < .001$). Furthermore, we found that the relationship between sex and grammar performance was fully mediated by performance on the KiSS.2 sentence repetition task, as the direct effect ($B = -0.037$, $p = .921$) was not even remotely significant, whereas for the indirect effect, a significant result was obtained ($ab = 1.122$, 95% CI[0.558, 1.701]).

Thus, we found evidence for a (full) mediation of sex differences in grammar by (sex differences in) PSTM.

Speech and language comprehension

Finally, we investigated speech and language comprehension. Again, the Mottier Test performance was chosen first as the mediator. As could be expected, a total effect of sex on performance in comprehension was observed ($B = 0.283$, $p = .004$). Sex predicted the mediator, which, in turn, predicted performance in comprehension ($B = 0.048$, $p < .001$). Furthermore, we found evidence that the relationship between

sex and comprehension performance was fully mediated by the Mottier Test performance, as the direct effect ($B = 0.170$, $p = .063$) barely failed statistical significance, whereas the indirect effect was significant ($ab = 0.113$, 95% CI[0.035, 0.209]).

Next, we conducted the analysis using performance on the KiSS.2 subtest of non-word repetition as the mediator. Sex predicted the mediator, which, in turn, predicted comprehension performance ($B = 0.192$, $p < .001$). Furthermore, we found that the relationship between sex and comprehension was fully mediated by the performance on the KiSS.2 non-word repetition task because the direct effect ($B = 0.165$, $p = .081$) did not reach significance, while the indirect effect did ($ab = 0.118$, 95% CI[0.040, 0.219]).

Finally, we conducted the analysis using performance on the KiSS.2 subtest of sentence repetition as the mediator. Sex predicted the mediator, which, in turn, predicted comprehension ($B = 0.087$, $p < .001$). Furthermore, we found that the relationship between sex and language comprehension was fully mediated by performance on the KiSS.2 sentence repetition task, as the direct effect ($B = 0.079$, $p = .349$) was not significant, whereas for the indirect effect, a significant finding was obtained ($ab = 0.204$, 95% CI[0.099, 0.328]).

To summarize the results, sex differences both in grammar and speech and language comprehension were fully mediated by PSTM measures. Figure 3 presents a visual summary for both domains.

Discussion

Sex differences in language competence

A large body of psycholinguistic research on sex differences in language development exists (e.g., Lange et al., 2016; for an overview, see Wallentin, 2009). That there is an early advantage for girls in regard to vocabulary acquisition, among other domains, that seems to decrease and then vanish with age can be considered a very robust finding (e.g., Lange et al., 2016; Toivainen et al., 2017; for an overview, see Wallentin, 2009; but see also Rice & Hoffman, 2015). Despite this plethora of research, one area of language development, namely PSTM, has been mostly neglected with respect to sex differences. Where relevant research exists, it resulted mostly in null or inconsistent findings. To be precise, most studies (e.g., Ash et al., 2017; Kazemi & Saeednia, 2017; Topbaş et al., 2014) have not found sex differences in PSTM performance. Only a few (e.g., Krishnan et al., 2017; Lange et al., 2016) found a slightly better performance by girls, while—to the best of our knowledge—one study found a male advantage (Farmani et al., 2018). Furthermore, many findings on sex differences in PSTM were mere side effects of the respective studies, as their goal was not to investigate sex differences in PSTM but differences in other linguistic domains or language development, in general, or to validate a language test such as the HASE (Schöler & Brunner, 2008). Therefore, with respect to sex differences in PSTM, there was a strikingly large and significant research gap, which is somewhat surprising given the importance of PSTM for language development (Baddeley, 2003), while acknowledging the robust finding of an early female advantage in language development (Wallentin, 2009).

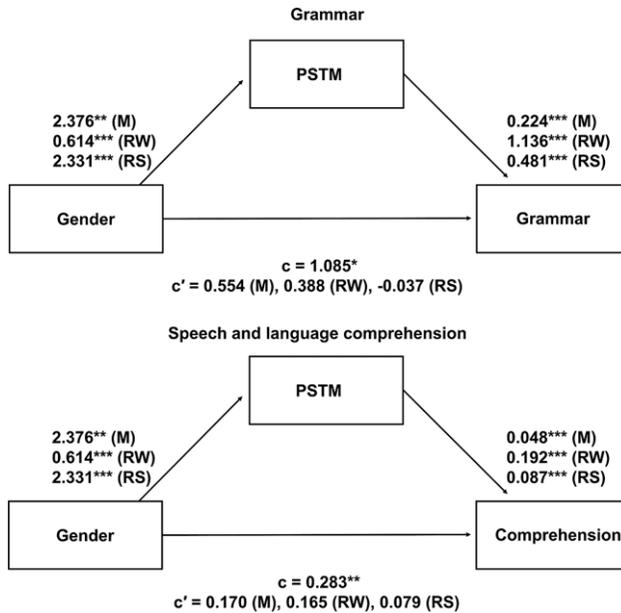


Figure 3. Full mediations between sex and performance on grammar/speech (top) and language comprehension (bottom) by measures of phonological short-term memory (Mottier Test, repetition of non-words, repetition of sentences).
 Notes: * $p < .05$, ** $p < .01$, *** $p < .001$. Abbreviations: PSTM = phonological short-term memory, M = Mottier Test; KiSS.2: RW = repetition of non-words, RS = repetition of sentences.

Hence, in the current study, we examined not only sex differences in articulation, vocabulary, grammar, and speech and language comprehension in 4-year-old children but also sex differences in PSTM performance by means of several tests involving the repetition of non-words and sentences.

In line with previous research (e.g., Lange et al., 2016), we found that girls performed better than boys in all linguistic domains, although not all differences were statistically significant after Bonferroni correction and although some effect sizes were small. Specifically, girls performed better than boys, particularly in articulation and vocabulary but also in the PSTM domain, that is, in the repetition of non-words as well as in the repetition of sentences.

We checked for several variables whether they were confounded with sex (e.g., age, length of kindergarten attendance, and intelligence). As there were no such confoundings, we are confident that we actually found differences between females and males (and not differences between other groups). It has to be noted though that we have only investigated sex differences in language competence in preschool children (for sex differences in language competence from childhood to adult age, see, for instance, Rice & Hoffman, 2015).

The mediation of sex differences in language competence by PSTM

Based primarily on the fundamental importance of PSTM for language development, particularly with respect to the acquisition of vocabulary (for an overview, see Baddeley, 2003; Szmalec et al., 2013) but also on the finding that girls outperformed boys in vocabulary, among other language domains, while also showing better PSTM performance, we further investigated whether the sex differences we found for articulation, vocabulary, grammar, and speech and language comprehension were mediated by sex differences in PSTM (i.e., in the repetition of non-words and sentences). To the best of our knowledge, our study is the first of this kind.

Indeed, mediation analyses revealed that the obtained sex differences in articulation and vocabulary were partially mediated by (sex differences in) PSTM, while sex differences in grammar and speech and language comprehension were fully mediated by such differences in PSTM. Yet it must be emphasized that sex differences in vocabulary and, possibly, even in articulation are relatively robust, while those in other domains (e.g., grammar; see above) are particularly small (cf. Lange et al., 2016).

The question arises how exactly sex differences in PSTM might lead to sex differences in language development. What are the cognitive mechanisms behind this relation? For now, we can only speculate on this, but deem the following to be likely. Taking vocabulary as an example, any new word has to enter and pass the PSTM successfully to be acquired (e.g., Newbury et al., 2015). So, if the PSTM constitutes a bottle neck for new words that are about to be acquired, individuals with larger or more advanced PSTM capacities (with girls having such an advantage over boys on average) will end up having larger vocabularies. While this seems reasonable, it automatically leads to another question, namely why girls have better PSTM abilities than boys on average to start with. Despite biological factors, for instance prenatal testosterone (e.g., Lange, 2015) or genetic factors (e.g., Galsworthy et al., 2000; Van Hulle et al., 2004), research comes into mind showing that girls and boys are treated and talked to differently in many ways (e.g., Fivush et al., 2000). A meta-analysis by Leaper et al. (1998), for instance, found that mothers talk more with their daughters than with their sons. There is a plethora of research demonstrating that such social factors (e.g., the quantity and quality of language input) contribute to children's language development (e.g., Adams et al., 2018; Huttenlocher et al., 2002; Pan et al., 2005; Pancsofar & Vernon-Feagans, 2006; Rowe, 2008, 2012; for an overview, see Hoff, 2006)—probably, among others, by improving the children's speech processing efficiency (Hurtado et al., 2008; Weisleder & Fernald, 2013). It has to be noted though that biological along with socio-cultural factors might best explain language development. For instance, in case of a correlation between child-directed parental speech on the one hand and language competence of the respective children on the other hand, genes and environments are probably not uncorrelated (Huttenlocher et al., 2002). Also, cross-cultural data indicate that an early female advantage in language competence is quite robust, indicating biological factors. However, this does not exclude social factors entirely (Eriksson et al., 2012).

Summary, conclusion, practical implications, and future research

A large body of research has demonstrated sex differences in early language development (e.g., Lange et al., 2016). In line with this, we found that girls performed better than boys, particularly in articulation and vocabulary. In addition to the existing research, we found that girls performed better on PSTM tasks (i.e., the repetition of non-words and sentences). Furthermore, sex differences in PSTM were able to explain sex differences in other linguistic domains. As stated above, future studies should replicate the respective findings of the present research, particularly those on sex differences in PSTM performance and on the mediation of sex differences in several linguistic domains by PSTM performance because the results of a single study are not as trustworthy as the results of many studies on a certain research topic. If sex differences in PSTM exist, it is crucial to find explanations for these differences. Hence, future research needs to identify the factors responsible for the sex difference in PSTM.

Our findings from the mediation analyses could turn out to be important for several reasons. One is that this is the first study of its kind, to the best of our knowledge. Another is that the present study underlines the importance of PSTM for language development, in general, and for explaining individual differences (cf. Baddeley, 2003; Szmalec et al., 2013), in particular—in our case, sex differences in language development. A third reason—given that the results of the study at hand can be replicated—is that the findings help explain sex differences in language development, for instance, with respect to vocabulary (see, for example, Adani & Capanec, 2019, and Lange et al., 2016, for a discussion on different [and competing] explanations of sex differences in language development). If sex differences in PSTM exist, it could be considered crucial to find explanations for these differences to be able to identify factors that could be used in language-assistance programs, particularly for boys. Future research could try to identify the factors responsible for the sex difference in PSTM to develop appropriate training programs, among other interventions. Hence, a fourth reason is that the study suggests, as a practical consequence, that language-training programs aimed at assisting boys, who are over-represented among children with relatively low language competence (for an overview, see, e.g., Adani & Capanec, 2019), might focus on PSTM. This can be derived not only from the fact that PSTM plays a decisive role in language development (Baddeley, 2003) but mainly from our finding that sex differences in several linguistic domains could be mediated by PSTM performance. Still, it has to be noted that replicating our findings on the mediating role of the PSTM should have priority. There are already several such programs aimed at short-term/working memory resources (see, for instance, Gathercole et al., 2019; Karousou & Nerantzaki, in press; von Bastian & Oberauer, 2013) that could aid children (particularly boys) to improve their PSTM competence and, thereby, potentially their language competence, in general, although we must be cautious, as more research is needed to clarify whether the effects of such training are not merely small and short-term and, furthermore, if the effects are generalizable across different domains (see Melby-Lervåg & Hulme, 2013). Before focusing on the practical application of the research results, however, further research is needed that investigates whether the mediation of sex differences in several areas of language competence by PSTM can be considered robust.

References

- Abdi, H. (2007). Bonferroni and Sidak corrections for multiple comparisons. In N. J. Salkind (Ed.), *Encyclopedia of measurement and statistics* (pp. 103–107). Sage.
- Adams, K. A., Marchman, V. A., Loi, E. C., Ashland, M. D., Fernald, A., & Feldman, H. M. (2018). Caregiver talk and medical risk as predictors of language outcomes in full term and preterm toddlers. *Child Development*, 89(5), 1674–1690.
- Adani, S., & Capanec, M. (2019). Sex differences in early communication development: behavioral and neurobiological indicators of more vulnerable communication system development in boys. *Croatian Medical Journal*, 60(2), 141–149. <https://doi.org/10.3325/cmj.2019.60.141>
- Adlof, S. M., & Patten, H. (2017). Nonword repetition and vocabulary knowledge as predictors of children's phonological and semantic word learning. *Journal of Speech, Language, and Hearing Research*, 60(3), 682–693.
- Andrade, J., & Baddeley, A. (2011). The contribution of phonological short-term memory to artificial grammar learning. *The Quarterly Journal of Experimental Psychology*, 64(5), 960–974.
- Ardila, A., Rosselli, M., Matute, E., & Inozemtseva, O. (2011). Gender differences in cognitive development. *Developmental Psychology*, 47(4), 984–990. <https://doi.org/10.1037/a002381>.
- Ash, A. C., Redmond, S. M., Timler, G. R., & Kean, J. (2017). The influence of scale structure and sex on parental reports of children's social (pragmatic) communication symptoms. *Clinical Linguistics & Phonetics*, 31(4), 293–312. <https://doi.org/10.1080/02699206.2016.1257655>
- Baddeley, A. D. (2003). Working memory and language: an overview. *Journal of Communication Disorders*, 36, 189–208. [https://doi.org/10.1016/S0021-9924\(03\)00019-4](https://doi.org/10.1016/S0021-9924(03)00019-4)
- Baddeley, A. D., Gathercole, S., & Papagno, C. (1998). The phonological loop as a language learning device. *Psychological Review*, 105(1), 158–73. <https://doi.org/10.1037/0033-295X.105.1.158>
- Baddeley, A. D., & Hitch, G. (1974). Working Memory. *Psychology of Learning and Motivation: Advances in Research and Theory*, 8, 47–89.
- Bauer, D. J., Goldfield, B. A., & Reznick, J. S. (2002). Alternative approaches to analyzing individual differences in the rate of early vocabulary development. *Applied Psycholinguistics*, 23(3), 313–335. <https://doi.org/10.1017/S0142716402003016>
- Befi-Lopes, D. M., Pereira, A. C., & Bento, A. C. (2010). Phonological representation of children with Specific Language Impairment (SLI). *Pro-Fono Revista de Atualização Científica*, 22(3), 305–310. <https://doi.org/10.1590/S0104-56872010000300025>
- Beltz, A. M., Blakemore, J. E. O., & Berenbaum, S. A. (2013). Sex differences in brain and behavioural development. In H. Tager-Flusberg, P. Rakic, & J. Rubenstein (Eds.), *Comprehensive developmental neuroscience: Vol. 3. Neural circuit development and function in the healthy and diseased brain* (pp. 467–499). Oxford, UK: Elsevier.
- Berglund, E., Eriksson, M., & Westerlund, M. (2005). Communicative skills in relation to gender, birth order, childcare and socioeconomic status in 18-month-old children. *Scandinavian Journal of Psychology*, 46, 485–491. <https://doi.org/10.1111/j.1467-9450.2005.00480.x>
- Bishop, D. V. M., North, T., & Donlan, C. (1996). Nonword repetition as a behavioural marker for inherited language impairment: Evidence from a twin study. *Journal of Child Psychology and Psychiatry*, 37(4), 391–403.
- Bleses, D., Vach, W., Slott, M., Wehberg, S., Thomsen, P., Madsen, T. O., & Basbøll, H. (2008). The Danish Communicative Developmental Inventories: Validity and main developmental trends. *Journal of Child Language*, 35, 651–669. <https://doi.org/10.1017/S0305000907008574>
- Bornstein, M. H., Hahn, C.-S., & Haynes, O. M. (2004). Specific and general language performance across early childhood: Stability and gender considerations. *First Language*, 24, 267–304. <https://doi.org/10.1177/0142723704045681>
- Bouchard, C., Trudeau, N., Sutton, A., Boudreault, M.-C., & Deneault, J. (2009). Gender differences in language development in French Canadian children between 8 and 30 months of age. *Applied Psycholinguistics*, 30(4), 685–707. <https://doi.org/10.1017/S0142716409990075>
- Burt, L., Holm, A., & Dodd, B. (1999). Phonological awareness skills of 4-year-old British children: An assessment and developmental data. *International Journal of Language and Communication Disorders*, 34(3), 311–335. <https://doi.org/10.1080/136828299247432>

- Casserly, E. D., & Pisoni, D.B. (2013). Nonword repetition as a predictor of long-term speech and language skills in children with cochlear implants. *Otology & Neurotology*, 34(3), 460–470.
- Chaney, C. (1992). Language development, metalinguistic skills, and print awareness in 3-year-old children. *Applied Psycholinguistics*, 13(4), 485–514.
- Chiat, S., & Roy, P. (2007). The preschool repetition test: An evaluation of performance in typically developing and clinically referred children. *Journal of Speech, Language, and Hearing Research*, 50, 429–443.
- Chiat, S., & Roy, P. (2013). Early predictors of language and social communication impairments at ages 9–11 years: A follow-up study of early-referred children. *Journal of Speech, Language, and Hearing Research*, 56(6), 1824–1836.
- Coady, J. A., & Evans, J. L. (2008). Uses and interpretations of non-word repetition tasks in children with and without specific language impairments (SLI). *International Journal of Language & Communication Disorders*, 43(1), 1–40. <https://doi.org/10.1080/13682820601116485>
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.
- Collette, F., Van der Linden, M., & Poncet, M. (2000). Working memory, long-term memory and language processing: Issues and future directions. *Brain and Language*, 71, 46–51.
- Conti-Ramsden, G., & Durkin, K. (2012). Language development and assessment in the preschool period. *Neuropsychology Review*, 22, 384–401. <https://doi.org/10.1007/s11065-012-9208-z>
- Dickinson, D. K., & Porche, M. V. (2011). Relation between language experiences in preschool classrooms and children's kindergarten and fourth-grade language and reading abilities. *Child Development*, 82(3), 870–886.
- D'Odorico, L., Assanelli, A., Franco, F., & Jacob, V. (2007). A follow-up study on Italian late talkers: Development of language, short-term memory, phonological awareness, impulsiveness, and attention. *Applied Psycholinguistics*, 28(1), 157–169. <https://doi.org/10.1017/S0142716406070081>
- Eriksson, M., Marschik, P. B., Tulviste, T., Almgren, M., Pérez Pereira, M., Wehberg, S., Marjanovič-Umek, L., Gayraud, F., Kovacevic, M., & Gallego, C. (2012). Differences between girls and boys in emerging language skills: Evidence from 10 language communities. *British Journal of Developmental Psychology*, 30, 326–343. <https://doi.org/10.1111/j.2044-835X.2011.02042.x>
- Estes, K., Evans, J. L., & Else-Quest, N. M. (2007). Differences in the nonword repetition performance of children with and without specific language impairment: A meta-analysis. *Journal of Speech, Language, and Hearing Research*, 50, 177–195.
- Euler, H. A., Holler-Zittlau, I., van Minnen, S., Sick, U., Dux, W., Zaretsky, Y., & Neumann, K., (2012). Psychometrische Gütekriterien eines Kurztests zur Erfassung des Sprachstands 4-jähriger Kinder [Validity criteria of a short test to assess speech and language competence in 4-year-olds]. *HNO*, 58(11), 1116–1123.
- Farmani, H., Sayyahi, F., Soleymani, Z., Zadeh Labbaf, F., Talebi, E., & Shourvazi, Z. (2018). Normalization of the non-word repetition test in Farsi-speaking children. *Journal of Modern Rehabilitation*, 12(4), 217–224. <https://doi.org/10.32598/JMR.V12.N4.217>
- Feldman, H. M., Dollaghan, C. A., Campbell, T. F., Kurs-Lasky, M., Janosky, J. E., & Paradise, J. L. (2000). Measurement properties of the MacArthur communicative development inventories at ages one and two years. *Child Development*, 71, 310–322.
- Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., Pethick, S. J., Tomasello, M., Mervis, C. B., & Stiles, J. (1994). Variability in early communicative development. *Monographs of the Society for Research in Child Development*, 59, i, iii–v, 1–185. <https://doi.org/10.2307/1166093>
- Fivush, R., Brotman, M. A., Buckner, J. P., & Goodman, S. H. (2000). Gender differences in parent-child emotion narratives. *Sex Roles*, 42(3/4), 233–253.
- Galsworthy, M. J., Dionne, G., Dale, P. S., & Plomin, R. (2000). Sex differences in early verbal and non-verbal cognitive development. *Developmental Science*, 3, 206–215. <https://doi.org/10.1111/1467-7687.00114>
- Gathercole, S. E., & Baddeley, A. D. (1990a). The role of phonological memory in vocabulary acquisition: A study of young children learning new names. *British Journal of Psychology*, 81(4), 439–454.
- Gathercole, S. E., & Baddeley, A. D. (1990b). Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory and Language*, 29(3), 336–360.
- Gathercole, S. E., Dunning, D. L., Holmes, J., & Norris, D. (2019). Working memory training involves learning new skills. *Journal of Memory and Language*, 105, 19–42.

- Girbau, D., & Schwartz, R. G. (2008). Phonological working memory in Spanish-English bilingual children with and without specific language impairment. *Journal of Communication Disorders*, 41(2), 124–145.
- Gray, S. (2003). Diagnostic accuracy and test-retest reliability of nonword repetition and digit span tasks administered to preschool children with specific language impairment. *Journal of Communication Disorders*, 36, 129–151. [https://doi.org/10.1016/s0021-9924\(03\)00003-0](https://doi.org/10.1016/s0021-9924(03)00003-0)
- Grimm, H. (2001). *SETK 3-5. Sprachentwicklungstest für drei- bis fünfjährige Kinder*. Hogrefe.
- Hayes, A. F. (2018). *Introduction to Mediation, Moderation, and Conditional Process Analysis, Second Edition (Methodology in the Social Sciences)* (2nd ed.). Guilford Press.
- Hayiou-Thomas, M. E., Dale, P. S., & Plomin, R. (2012). The etiology of variation in language skills changes with development: A longitudinal twin study of language from 2 to 12 years. *Developmental Science*, 15, 233–249. <https://doi.org/10.1111/j.1467-7687.2011.01119.x>
- Hoff, E. (2006). How social contexts support and shape language development. *Developmental Review*, 26, 55–88.
- Holler-Zittlau, I., Euler, H. A., & Neumann, K. (2011). Kindersprachscreening (KiSS) – das hessische Verfahren zur Sprachstandserfassung [Kindersprachscreening (KiSS) – the Hessian language test]. *Sprachheilarbeit*, 5(6), 263–268.
- Hurtado, N., Marchman, V. A., & Fernald, A. (2008). Does input influence uptake? Links between maternal talk, processing speed and vocabulary size in Spanish-learning children. *Developmental Science*, 11(6), F31–F39. <https://doi.org/10.1111/j.1467-7687.2008.00768.x>
- Huttenlocher, J., Vasilyeva, M., Cymerman, E., & Levine, S. (2002). Language input and child syntax. *Cognitive Psychology*, 45, 337–374.
- Jackson, E., Leitao, S., & Claessen, M. (2016). The relationship between phonological short-term memory, receptive vocabulary, and fast mapping in children with specific language impairment. *International Journal of Language & Communication Disorders*, 51(1), 61–73.
- Jones, G. (2016). The influence of children's exposure to language from two to six years: The case of non-word repetition. *Cognition*, 153, 79–88. <https://doi.org/10.1016/j.cognition.2016.04.017>
- Kapalková, S., Polišenská, K., & Vicenová, Z. (2013). Non-word repetition performance in Slovak-speaking children with and without SLI: novel scoring methods. *International Journal of Language & Communication Disorders*, 48(1), 78–89. <https://doi.org/10.1111/j.1460-6984.2012.00189.x>
- Karousou, A., & Nerantzaki, T. (in press). Phonological memory training and its effect on second language vocabulary development. *Second Language Research*. <https://doi.org/10.1177/0267658319898514>
- Kazemi, Y., & Saednia, S. (2017). The clinical examination of non-word repetition tasks in identifying Persian-speaking children with primary language impairment. *International Journal of Pediatric Otorhinolaryngology*, 93, 7–12. <https://doi.org/10.1016/j.ijporl.2016.11.028>
- Kiese-Himmel, C., & Risse, T. (2009). Normen für den Mottier-Test bei 4- bis 6-jährigen Kindern [Norms for the Mottier Test for 4- to 6-year-old children]. *HNO*, 57, 943–948.
- Kovas, Y., Hayiou-Thomas, M. E., Oliver, B., Dale, P. S., Bishop, D. V. M., & Plomin, R. (2005). Genetic influences in different aspects of language development: The etiology of language skills in 4.5-year-old twins. *Child Development*, 76(3), 632–651.
- Krishnan, S., Alcock, K. J., Carey, D., Bergström, L., Karmiloff-Smith, A., & Dick, F. (2017). Fractionating nonword repetition: The contributions of short-term memory and oromotor praxis are different. *PLoS One*, 12(7), e0178356. <https://doi.org/10.1371/journal.pone.0178356>
- Lange, B. P. (2015). Digit ratio as a predictor of language development and media preferences in kindergarten children. *Acta Linguistica*, 9(2), 70–83.
- Lange, B. P., Euler, H. A., & Zaretsky, E. (2016). Sex differences in language competence of three- to six-year old children. *Applied Psycholinguistics*, 37(6), 1417–1438. <https://doi.org/10.1017/S0142716415000624>
- Lange, B. P., Zaretsky, E., Schwarz, S., & Euler, H. A. (2014). Words won't fail: Experimental evidence on the role of verbal proficiency in mate choice. *Journal of Language and Social Psychology*, 33(5), 482–499. <https://doi.org/10.1177/0261927x13515886>
- Leaper, C., Anderson, K. J., & Sanders, P. (1998). Moderators of gender effects on parents' talk to their children: a meta-analysis. *Developmental Psychology*, 34(1), 3–27.
- Letts, C., Edwards, S., Sinka, I., Schaefer, B., & Gibbons, W. (2013). Socio-economic status and language acquisition: Children's performance on the new Reynell Developmental Language Scales. *International Journal of Language & Communication Disorders*, 48(2), 131–143.

- Lutchmaya, S., Baron-Cohen, S., & Raggatt, P. (2001). Foetal testosterone and vocabulary size in 18- and 24-month-old infants. *Infant Behavior and Development*, 24(4), 418-424.
- Martin, R. C., & Slevc, L. R. (2014). Language production and working memory. In M. Goldrick, V. Ferreira & M. Miozzo (Eds.), *The Oxford handbook of language production* (pp. 437-450). Oxford University Press.
- Martinelli, V. (2013). Sex differences and variability in phonological sensitivity among primary school children. *Malta Review of Educational Research*, 7(1), 1-26.
- Mealey, L. (2000). *Sex differences: Development and evolutionary strategies*. Academic Press.
- Melby-Lervåg, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental Psychology*, 49(2), 270-291.
- Montgomery, J. W., Magimairaj, B. M., & Finney, M. C. (2010). Working memory and specific language impairment: An update on the relation and perspectives on assessment and treatment. *American Journal of Speech-Language Pathology*, 19(1), 78-94. [https://doi.org/10.1044/1058-0360\(2009/09-0028\)](https://doi.org/10.1044/1058-0360(2009/09-0028))
- Mottier, G. (1951). Über Untersuchungen der Sprache lesegestörter Kinder [On language tests with dyslexic children]. *Folia Phoniatica*, 3, 170-177.
- Neugebauer, U., & Becker-Mrotzek, M. (2013). *Die Qualität von Sprachstandsverfahren im Elementarbereich. Eine Analyse und Bewertung [The Quality of Language Tests for Pre-schoolers. Analysis and Evaluation]*. The Mercator Institute for Literacy and Language Education.
- Newbury, J., Klee, T., Stokes, S. F., & Moran, C. (2015). Exploring expressive vocabulary variability in two-year-olds: The role of working memory. *Journal of Speech, Language, and Hearing Research*, 58, 1761-1772.
- Nicolay, A. C., & Poncelet, M. (2013). Cognitive abilities underlying second-language vocabulary acquisition in an early second-language immersion education context: A longitudinal study. *Journal of Experimental Child Psychology*, 115(4), 655-671.
- Noel, M., Peterson, C., & Jesso, B. (2008). The relationship of parenting stress and child temperament to language development among economically disadvantaged preschoolers. *Journal of Child Language*, 35, 823-843.
- Pan, B. A., Rowe, M. L., Singer, J. D., & Snow, C. E. (2005). Maternal correlates of growth in toddler vocabulary production in low-income families. *Child Development*, 76(4), 763-782.
- Pancsofar, N., & Vernon-Feagans, L. (2006). Mother and father language input to young children: Contributions to later language development. *Journal of Applied Developmental Psychology*, 27(6), 571-587.
- Pelczarski, K. M., & Yaruss, J. S. (2016). Phonological memory in young children who stutter. *Journal of Communication Disorders*, 62, 54-66. <https://doi.org/10.1016/j.jcomdis.2016.05.006>
- Radeborg, K., Barthelom, E., Sjöberg, M. & Sahlén, B. (2006). A Swedish non-word repetition test for preschool children. *Scandinavian Journal of Psychology*, 47, 187-192.
- Ramachandra, V., Hewitt, L. E., & Brackenbury, T. (2011). The relationship between phonological memory, phonological sensitivity, and incidental word learning. *Journal of Psycholinguistic Research*, 40, 93-109.
- Raven, J.C. (2009). *Coloured Progressive Matrices*. Pearson Assessment and Information GmbH.
- Reichenbach, K., Bastian, L., Rohrbach, S., Gross, M., & Sarrar, L. (2016). Cognitive functions in preschool children with specific language impairment. *International Journal of Pediatric Otorhinolaryngology*, 86, 22-26.
- Rice, M. L., & Hoffman, L. (2015). Predicting vocabulary growth in children with and without specific language impairment: A longitudinal study from 2;6 to 21 years of age. *Journal of Speech, Language, and Hearing Research*, 58, 345-359.
- Rowe, M. L. (2008). Child-directed speech: relation to socioeconomic status, knowledge of child development and child vocabulary skill. *Journal of Child Language*, 35(1), 185-205. <https://doi.org/10.1017/S0305000907008343>
- Rowe, M. L. (2012). A longitudinal investigation of the role of quantity and quality of child-directed speech in vocabulary development. *Child Development*, 83(5), 1762-1774. <https://doi.org/10.1111/j.1467-8624.2012.01805.x>
- Roy, P., & Chiat, S. (2004). A prosodically controlled word and nonword repetition task for 2- to 4-year-olds: Evidence from typically developing children. *Journal of Speech, Language, and Hearing Research*, 47, 223-234.

- Rujas, I., Mariscal, S., Casla, M., Lázaro, M., & Murillo, E. (2017). Word and nonword repetition abilities in Spanish language: Longitudinal evidence from typically developing and late talking children. *The Spanish Journal of Psychology*, 20, E72.
- Schöler, H., & Brunner, M. (2008). *Heidelberger auditives Screening in der Einschulungsuntersuchung (HASE)* (2. überarbeitete und erweiterte Auflage) [Heidelberg Auditory Screening in the School-Enrolment Examination (HASE) (2nd revised and extended edition)]. Westra.
- Szmaliec, A., Brysbaert, M., & Duyck, W. (2013). Working memory and (second) language processing. In J. Altarriba & L. Isurin (Eds.), *Memory, language, and bilingualism: Theoretical and applied approaches* (pp. 74–94). Cambridge: Cambridge University Press.
- Stokes, S. F., & Klee, T. (2009). Factors that influence vocabulary development in two-year-old children. *The Journal of Child Psychology and Psychiatry*, 50(4), 498–505. <https://doi.org/10.1111/j.1469-7610.2008.01991.x>
- Stromswold, K. (2001). The heritability of language: A review and meta-analysis of twin, adoption, and linkage studies. *Language*, 77(4), 647–723.
- Tager-Flusberg, H. (2005). Designing studies to investigate the relationships between genes, environments, and developmental language disorders. *Applied Psycholinguistics*, 26, 29–39.
- Taylor, C. L., Christensen, D., Lawrence, D., Mitrou, F., & Zubrick, S. R. (2013). Risk factors for children's receptive vocabulary development from four to eight years in the longitudinal study of Australian children. *Plos One*, 8(9), e73046.
- Thomas, M. S. C., Forrester, N. A., & Ronald, A. (2013). Modeling socioeconomic status effects on language development. *Developmental Psychology*, 49(12), 2325–2343.
- Toivainen, T., Papageorgiou, K. A., Tosto, M. G., & Kovas, Y. (2017). Sex differences in non-verbal and verbal abilities in childhood and adolescence. *Intelligence*, 64, 81–88. <https://doi.org/10.1016/j.intell.2017.07.007>
- Topbaş, S., Kaçar-Kütükçü, D., & Kopkalli-Yavuz, H. (2014). Performance of children on the Turkish Nonword Repetition Test: Effect of word similarity, word length, and scoring. *Clinical Linguistics & Phonetics*, 28(7–8), 602–616. <https://doi.org/10.3109/02699206.2014.927003>
- Torrington Eaton, C., Newman, R. S., Ratner, N. B., Rowe, M. L. (2015). Non-word repetition in 2-year-olds: Replication of an adapted paradigm and a useful methodological extension. *Clinical Linguistics & Phonetics*, 29(7), 523–535. <https://doi.org/10.3109/02699206.2015.1029594>
- Truong, D. T., Shriberg, L. D., Smith, S. D., Chapman, K. L., Scheer-Cohen, A. R., DeMille, M. M., Adams, A. K., Nato, A. Q., Wijisman, E. M., Eicher, J. D., & Gruen, J. R. (2016). Multipoint genome-wide linkage scan for nonword repetition in a multigenerational family further supports chromosome 13q as a locus for verbal trait disorders. *Human Genetics*, 135(12), 1329–1341.
- Tunmer, W. E., Bowey, J. A., & Grieve, R. (1983). The development of young children's awareness of the word as a unit of spoken language. *Journal of Psycholinguistic Research*, 12(6), 567–594.
- Van Dyke, J. A. (2012). The role of memory in language and communication. In R. Peach & L. Shapiro (Eds.), *Cognition and acquired language disorders: A process-oriented approach* (pp. 94–120). Mosby Elsevier.
- Van Hulle, C. A., Goldsmith, H. H., & Lemery, K. S. (2004). Genetic, environmental, and gender effects on individual differences in toddler expressive language. *Journal of Speech, Language, and Hearing Research*, 47, 904–912.
- Von Bastian, C. C., & Oberauer (2013). Distinct transfer effects of training different facets of working memory capacity. *Journal of Memory and Language*, 69, 36–58.
- Wadsworth, S. J., DeFries, J. C., Fulker, D. W., Olson, R. K., & Pennington, B. F. (1995). Reading performance and verbal short-term memory: A twin study of reciprocal causation. *Intelligence*, 20, 145–167.
- Wallentin, M. (2009). Putative sex differences in verbal abilities and language cortex: A critical review. *Brain & Language*, 108, 175–183. <https://doi.org/10.1016/j.bandl.2008.07.001>
- Weisleder, A., & Fernald, A. (2013). Talking to children matters: Early language experience strengthens processing and builds vocabulary. *Psychological Science*, 24(11) 2143–2152. <https://doi.org/10.1177/0956797613488145>
- Willinger, U., Schmoeger, M., Deckert, M., Eisenwort, B., Loader, B., Hofmair, A., & Auff, E. (2017). Screening for specific language impairment in preschool children: Evaluating a screening procedure including the token test. *Journal of Psycholinguistic Research*, 46(5), 1237–1247. <https://doi.org/10.1007/s10936-017-9493-z>

- Zaretsky, E., Euler, H. A., Neumann, K., & Lange, B. P. (2014). Sociolinguistic predictors of language deficits in pre-school children with and without immigrant background. Talk at the Asian Conference on Language Learning, Osaka, Japan, April 17–20, 2014.
- Zaretsky, E., & Lange, B. P. (2017). Sociolinguistic factors associated with the subjectively and objectively measured language development in German preschoolers in three follow-up studies. *Linguistics*, 55(1), 39–65. <https://doi.org/10.1515/ling-2016-0036>.
- Zaretsky, E., Lange, B. P., Euler, H. A., Robinson, F., & Neumann, K. (2017). Pre-schoolers who stutter score lower in verbal skills than their non-stuttering peers. *Buckingham Journal of Language and Linguistics*, 10, 96–115. <https://doi.org/10.5750/bjll.v10i0.1171>
- Zell, E., Krizan, Z., & Teeter, S. R. (2015). Evaluating gender similarities and differences using metasynthesis. *American Psychologist*, 70, 10–20. <https://doi.org/10.1037/a0038208>