Sex Differences in Language Acquisition by Pre-School Children: A Rapid Review

Motivation: Boys underperform at school. One hypothesis is that boys' poorer spoken language and comprehension at the start of schooling, aged 5, might be part of the reason, the initial disadvantage being amplified by the reduced engagement with school lessons which results.

Questions to Address: (a) Do boys have, on average, poorer language acquisition than girls prior to school age?; (b) If so, what biological and environmental factors are known to contribute to this sex difference?

Method: Literature review. The published literature is vast. This rapid review makes no pretence of completeness. However, it is believed that the 39 studies identified are sufficient to faithfully represent the major findings. Studies include many different languages.

Key Findings

[1] Yes, boys do have, on average, poorer language acquisition than girls from the earliest age to 5 years. Virtually all studies agree on this, studies coming to the opposite conclusion are very rare.

[2] This result is stable across languages and cultures.

[3] However the size of boys' language disadvantage is generally small though some studies have reported medium to large effects (Table 1 and Figure 1).

[4] Whether the sex gap increases or decreases over the first five years of life was inconsistent between studies (Figure 2 is one illustration).

[5] The main findings of 18 studies of language acquisition by sex are given in brief in Table 3.

[6] One recent study identified that most, or all, of boys' language disadvantages could be attributed to poorer phonological short-term memory at this age (Ref. A1.12). Another pointed to the delay in audiovisual integration for male relative to female children (Ref. A4.1).

[7] Most studies (8 out of 11 listed in Table 4) conclude that both mothers and fathers are more verbally engaged with girls than with boys, though this is not invariably the case. Effect sizes are given in Table 2.

[8] However, there are some indications that the sex of the child *per se* is more significant than parental speech patterns (e.g., Ref. B3.1).

[9] It is well established that the average male and average female brains differ in a number of structural features. Less well established are differences in function related to these structural differences.

[10] It has been argued that the functional organization of the female brain gives women an inherent advantage in the acquisition of communication and language system over men (see Table 5 for a summary of 10 studies).

[11] There is a consensus that boys' speech is more left-right hemisphere asymmetric than in girls.

[12] There is evidence that the right hemisphere develops more slowly in boys, consistent with [11].

[13] There is some evidence that sex effects may be partly a surrogate for physical maturation rates, with early maturing adolescents performing better on tests of verbal than spatial abilities and vice-versa for late maturing adolescents. However this does not relate to pre-school age children.

[14] The tendency for better verbal ability to correlate with poorer spatial ability, and vice-versa, has been related to foetal testosterone exposure (and hence sex) and grey matter volume, see Figure 3, and this is applicable at younger ages, even in the first month (Refs.5.1a,b).

[15] The studies listed by the meta-analysis of Ref.S1a have indicated a wide range of structural differences in average brains by sex, summarised in Table 6. Of the 46 studies included in that meta-analysis, 33 showed sex differences whilst 13 did not (noting that these studies span ages from a few weeks to adult). Some, but not all, the identified brain differences are believed to be significant to language.

Summary: It is beyond question that boys, on average, have poorer speech and verbal dexterity than girls when they start school. Both parental speech patterns and structural brain differences may contribute to this sex difference, but it appears that brain differences may be the more significant. This disadvantage to boys at age five can only impact adversely on their ability to learn effectively in the early school years.

Further Research Required: Whether boys' pre-school disadvantage in language acquisition is a significant contributor to their later underperformance, especially in reading and writing, has not been addressed here. Potentially, such an association could be identified in longitudinal studies relating pre-school language in individuals to later school performance. However, causality will remain problematic.

Indicative Quotes from the 39 sources can be found in the Appendix which also specifies the search criteria used and the limitations of this rapid review.

The Author of this rapid review (R.Bradford) is a generalist researcher, not a specialist in this subject area or discipline. He has publications across engineering, physics, psychology and sociology. He is currently an Honorary Senior Research Fellow with the University of Bristol, Engineering Department.

References

Ref	URL / link
A1.1	Syntax and Vocabulary of Mothers' Speech to Young Children: Age and Sex Comparisons (psu.edu)
A1.2	sjny467-sers-NY00008874.dvi (whitman.edu)
A1.2a	MOTHERS AND TWO-YEAR-OLDS: A STUDY OF SEX-DIFFERENTIATED ASPECTS OF VERBAL INTERACTION - Cherry - 1975 - ETS Research Bulletin Series - Wiley Online Library
A1.2b	A Comparison of Fathers' and Mothers' Involvement in Childcare and Stimulation Behaviors During Free-Play with Their Infants at 9 and 15 Months | SpringerLink
A1.2c	Vocal communication between parents and infants - ScienceDirect
A1.2d	Fathers' and mothers' speech to young infants (springer.com)
A1.4	ptpmcrender.fcgi (europepmc.org)
A1.5	Speech and Language Development in 41 Children with Sex Chromosome Anomalies | Pediatrics | American Academy of Pediatrics (aap.org)
A1.6	Sex differences in cerebral organization for speech and praxic functions. - PsycNET (apa.org)
A1.7	The influence of sex on the development of lateralization of speech - ScienceDirect
A1.8	Sex Differences in Cognition: A Function of Maturation Rate? (science.org)
A1.9	Risk Factors for Speech Delay of Unknown Origin in 3-Year-Old Children - Campbell - 2003 - Child Development - Wiley Online Library
A1.10	Sex differences in intrahemispheric organization of speech | Behavioral and Brain Sciences | Cambridge Core
A1.11	Screening for Speech and Language Delay in Preschool Children: Systematic Evidence Review for the US Preventive Services Task Force | Pediatrics | American Academy of Pediatrics (aap.org)
A1.12	Sex differences in language competence of four-year-old children: Female advantages are mediated by phonological short-term memory
A1.13	Full article: A short-form version of the Australian English communicative development inventory (tandfonline.com)

A1.14	Clinical and sociodemographic findings in a cohort of 4632 pediatric patients with language, speech and learning disorders
S1	Sex differences in early communication development: behavioral and neurobiological indicators of more vulnerable communication system development in boys (nih.gov)
S1a	A systematic literature review of sex differences in childhood language and brain development - ScienceDirect
S1b	Some Possible Explanations of Sex Differences in Language Development and Disorders: The Journal of Psychology: Vol 35, No 1 (tandfonline.com)
S1c	Sex differences in language competence of 3- to 6-year-old children | Applied Psycholinguistics | Cambridge Core
S1d	Gender differences in children's language: a meta-analysis of Slovenian studies
S1e	Variability in Early Communicative Development on JSTOR
S1f	Late Language Emergence at 24 Months: An Epidemiological Study of Prevalence, Predictors, and Covariates | Journal of Speech, Language, and Hearing Research (asha.org)
S1g	Gender ratio and cognitive profiles in dyslexia: a cross-national study | SpringerLink
B1.1	Effect of sex and dyad composition on speech and gesture development of singleton and twin children
B1.1a	Communicative skills in relation to gender, birth order, childcare and socioeconomic status in 18-month-old children - BERGLUND - 2005 - Scandinavian Journal of Psychology - Wiley Online Library
B1.1b	Differences between girls and boys in emerging language skills: Evidence from 10 language communities - Eriksson - 2012 - British Journal of Developmental Psychology - Wiley Online Library
B1.1c	Gender differences in verbal ability: A meta-analysis - ProQuest
B1.1d	Variability in Early Communicative Development on JSTOR
B1.1e	Sex differences in syntactic development: Evidence from Cantonese-speaking preschoolers in Hong Kong: International Journal of Behavioral Development: Vol 26, No 6 (tandfonline.com)
B3.1	Processes in language acquisition: the roles of gender, attention, and maternal encouragement of attention over time | Journal of Child Language | Cambridge Core
A2.1	Frontiers | Neurobiological Sex Differences in Developmental Dyslexia | Psychology (frontiersin.org)
A3.1	ALL OUR SONS: THE DEVELOPMENTAL NEUROBIOLOGY AND NEUROENDOCRINOLOGY OF BOYS AT RISK - Schore - 2017 - Infant Mental Health Journal - Wiley Online Library

A4.1	Frontiers | Sex differences in multisensory speech processing in both typically developing children and those on the autism spectrum | Neuroscience (frontiersin.org)
A4.1a	Moderators of gender effects on parents' talk to their children: A meta-analysis. - PsycNET (apa.org)
A5.1	Gender and patterns of language development in mother-toddler and father-toddler dyads - Gretchen S. Lovas, 2011 (sagepub.com)
A5.1a	Sex hormone testosterone affects language organization in th... : NeuroReport (lww.com)
A5.1b	Gender Differences in the Development of EEG Coherence in Normal Children: Developmental Neuropsychology: Vol 16, No 3 (tandfonline.com)
A5.2	The Dynamics of Age and Sex in the Development of Mother–Infant Vocal Communication Between 3 and 11 Months - Sung - 2013 - Infancy - Wiley Online Library

Appendix

Search Definition

(A) Goole Scholar using the following keywords,

A.1 "speech development by sex", first 90 hits examined

A.2 "neurobiology speech development sex", top 20 hits examined

A.3 "developmental neurobiology boys at risk" , top 10 hits examined

A.4 "speech development brain sex", top 20 hits examined

A.5 "mothers speech patterns to children by sex", top 20 hits examined

(B) Journal of Child Language using the following keywords,

B.1 "speech development sex", top 60 hits examined

B.2 "gender speech development", top 20 hits examined

B.3 "gender language development", top 20 hits examined

(C) Journal "Child Development" using the following keywords,

C.1 "speech development sex", top 20 hits examined.

In addition, the references from several of the above sources were included. This resulted in the 39 relevant references listed above.

Focus & Limitations

The focus was on typical, or average, development trajectories. Both sexes will be subject to wide distributions of development speeds, and large overlaps can be anticipated. This is often expressed as "the sexes are more similar than they are different". The focus here is on differences in means.

Differences in variances are not considered except as incidentals. Possible sex differences in variances might lead to very different gaps at the extremes than at the mean (e.g., the slower development of the average boy does not necessarily mean that boys at, say, the one-percentile are also slower than one-percentile girls – often quite the opposite).

Pathologies such as autism spectrum or ADHD or other such conditions are not considered explicitly, but studies including such subjects have been used where they shed light on sex differences. This is apposite because virtually all abnormal conditions which adversely affect language are far more prevalent in boys than girls. Hence such conditions will contribute to the overall underperformance of

boys. However, non-pathological boys also underperform and are the main focus of this review.

Interpretational Difficulties

Social science studies are notoriously prone to reproducibility problems, with independent studies of the same factors almost always producing a range of differing results, some conflicting. I have no magical solution to this. However, it indicates a need to compile sources in an unbiased manner, and then to hope that the most reliable indication of the underlying reality will be given by the dominant trend. But there is no guarantee that this will actually be the case, especially if studies arise from a social or academic milieu which has unrecognised biases.

Publication bias is a real phenomenon, in which null results are less likely to be reported. This may lead to an under-reporting of work which reveals no sex differences.

Even notionally quantified (numerically based) studies will be prone to such cultural biases because it is invariably the case that observers will have considerable leeway in interpreting what they observe in subjects, and this is particularly marked where sex is involved as human cultures remain strongly skewed in gender perceptions.

Studies of sex differences will be particularly prone to such skews because there is an orthodoxy (even an ideology) which perceives any observed sex differences as being, of necessity, socially conditioned rather than biological. For example, in classifying different types of parents' speech, is a reported emotional tonality for use with girls, and a more 'functional' content with boys, more in the observer's perception than in reality? It is not possible to tell if a given study is affected by such biases.

That this may be a real problem is confirmed by Ref.B1.1c which found "*a significant difference in effect sizes for those studies whose first author was male compared with those whose first author was female, with female authors reporting a larger difference and therefore greater female superiority in performance*".

Meta-analyses should, in principle, do the task of reviewing the studies for us. But all meta-analyses reduce an initially large volume of trawled studies down to a much smaller number of studies which meet some criteria for relevance and lack of bias. But the criteria applied, and how they are applied, are, in truth, another means of introducing bias. Consequently, whilst meta-analyses are of particular interest, they should not be seen as a replacement for one's own trawl of the literature.

Quotes from Publications

As early as 1953, Dorothea McCarthy wrote in Ref.S1b,

"There has appeared in the literature considerable evidence indicating that American white boys are slightly later than girls in practically all aspects of language development which show development trends with age. These differences are seldom statistically significant, but the careful observer cannot ignore the amazing consistency with which these small differences appear in one investigation after another, each being conducted by a different experimenter, employing different techniques, different subjects, and sampling different geographical populations…..Although the development differences between the sexes are small in magnitude, they seem to be of considerable importance for the later acquisition of the more complex and secondary language forms for the effects seem to be cumulative." (my emphasis)

From Ref.S1 (Adani, 2019),

"All significant effects were in favour of girls"

"It seems that boys have "weaker" or "slower" capacities for language acquisition. Boys represent more than 70% of late talkers and just 30% of early talkers"

"During the first years of life, girls on average acquire language faster than boys and have larger vocabulary. For example, at 16 months, girls have a vocabulary of 95 words, while boys have a vocabulary of 25 words"

"Although documented sex differences in the prevalence of various communication, language, and speech-related conditions and disorders vary in different studies (sometimes largely), data consistently show (almost without any exceptions!) that boys have a significantly higher prevalence of all the conditions affecting communication, speech, and language."

From Ref.S1d (Marjanovic, 2017) this quote,

"In our opinion, special emphasis should be placed on providing equal opportunities and support for language development of both genders, both in the home environment as well as within institutions (e.g., preschools, primary and secondary schools), so that the small gender differences in early language ability are not multiplied and increased throughout the child's development and influenced by stereotypical differential behaviour and implicit theories of adults." (my emphasis)

From Ref.A1.2 (Clearfield, 2006)

"Mothers of daughters made more interpretations and engaged in more conversation with their daughters, whereas mothers of sons made more comments and attentionals, which were typified by instructions rather than conversation. Furthermore, mothers interacted more with their daughters than with their sons across all ages. Overall, these results demonstrate that mothers transmit different messages to their male and female infants, both through language and interaction, which may contribute to infants' gender role development."

From Ref.S1c (Lange, 2016)

"The relatively small developmental sex differences in verbal abilities found could be explained, for instance, by sex-different maturational rates. Females seem to mature faster than males, especially at young ages, and early maturation is correlated with better verbal abilities. Accordingly, language-related sex differences seem to be affected by biological factors, as can be observed by referring to genetic aspects, as well as to hormonal effects. Transsexuals, for instance, experience a large decrease in performance in verbal fluency tests after androgen therapy. Women seem to have greater verbal abilities (e.g., verbal fluency) in the middle of their menstrual cycle, when progesterone and estradiol levels are high.

From Ref.B1.1 (Ozturk, 2021)

Girls outperform boys in nearly all domains of language development including their vocabulary development. More specifically, girls develop larger vocabularies, producing greater diversity of words than boys, at both the earlier and the later ages, as assessed by parental checklist measures. The sex differences become evident not only in vocabulary but also in children's emerging syntactic abilities. Three- to five-year-old girls produce longer sentences with more diverse and complex structures than boys in one-on-one interactions with their parents. These patterns remain similar in the onset of first sentences. An earlier large-scale study (7078 girls, 6705 boys) with 0;8-2;6-year-old children, using parent checklists, showed that girls produce their first sentences earlier than boys.

From Ref.A5.1 (Lovas, 2011)

"Language development is a domain in which gender differences are already well established. The female advantage in verbal ability is one of the few gender differences considered to be robust. Individual studies of verbal abilities do show some inconsistency. However, when differences are found, they favour females. Females produce sounds at an earlier age, use words sooner, develop larger vocabularies, display greater grammatical complexity, spell better, and read sooner

than males. Females also produce a higher quantity of verbal communication. These early gender differences are fairly small in size and tend to disappear around age 5."

"There is general consensus that brain development in males is also delayed, resulting in infant gender differences in left hemisphere maturity and in the lateralization and organization of function within the brain."

"These findings have implications not only for gender differences in language use but for gender development more generally. Regardless of differences in the contexts for language use between parent–daughter and parent–son dyads, or whether the differences are being driven by increasing parent differentiation between sons and daughters or by increasing differences in the language ability of daughters and sons, the emerging picture is one in which daughters are being given ample opportunity to practice verbal exchange with both parents, while sons are learning less about verbal exchange with both mothers and fathers, but especially with fathers. Sons may therefore be learning very early that talking with complexity is not something that is done or is encouraged, especially with other males and perhaps not with anyone."

From Ref.A3.1 (Schore, 2017)

Why are boys at risk? To address this question, I use the perspective of regulation theory to offer a model of the deeper psycho-neurobiological mechanisms that underlie the vulnerability of the developing male. The central thesis of this work dictates that significant gender differences are seen between male and female social and emotional functions in the earliest stages of development, and that these result from not only differences in sex hormones and social experiences but also in rates of male and female brain maturation, specifically in the early developing right brain.

Table 1: Size of Sex Difference in Measured Speech Ability

Ref.	Effect Size*	Effect Size Measure
A1.9	2.19	OR@ for speech delay
S1c	0.11 [0.04,0.21] (1)	Cohen's d
S1c	0.46 [0.44,0.49] (1)	p̂ probability of superiority
S1d	0.11 [0,0.53] (2)	Cohen's d
S1e	0.02	Cohen's d
S1f	2.74 [1.96,3.84]	OR for Late Language Emergence
S1g	1.5 (3)	OR for dyslexia
A1.12	0.48 [0.20,0.75] (4)	Cohen's d, various tests (see also Fig.1)
A1.14	2.64	OR language or learning disorders
B1.1a	2.6 – 4.7	Regression beta for gender
B1.1b	1.16 [1.01,1.35]	Ratio of word test scores
B1.1c	0.11 [0.10,0.12]	120 studies combined (weighted)
B1.1c	0.33 [0.20,0.46]	Speech production, 12 studies average
B1.1d	1.15 to 1.35	Ratio of test scores at 30 mths, Fig.2
B1.1e	1.14	Ratio of mean length of utterances (MLU)
B1.1e	0.73	Cohen's d for MLU (my estimate)

** to boys' disadvantage in all cases* *@OR = Odds Ratio*

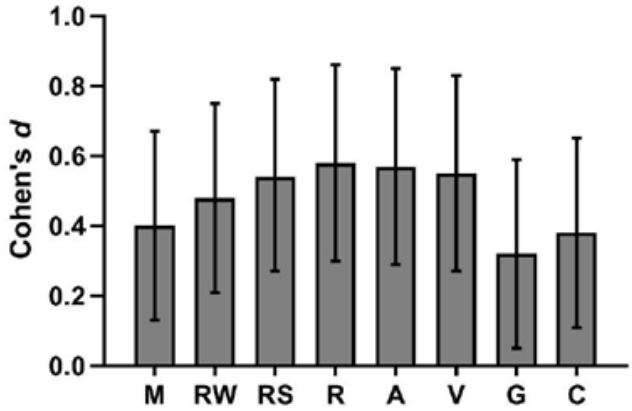
(1) *average for measures of vocabulary, grammar, comprehension, articulation and repetition*

(2) *For older children, aged 8 to 15 years, three samples gave large d: 0.56, 0.84 and 1.03*

(3) *Spanish data. Other countries report typically between 1.5 and 2.0*

(4) *Average over 8 types of test*

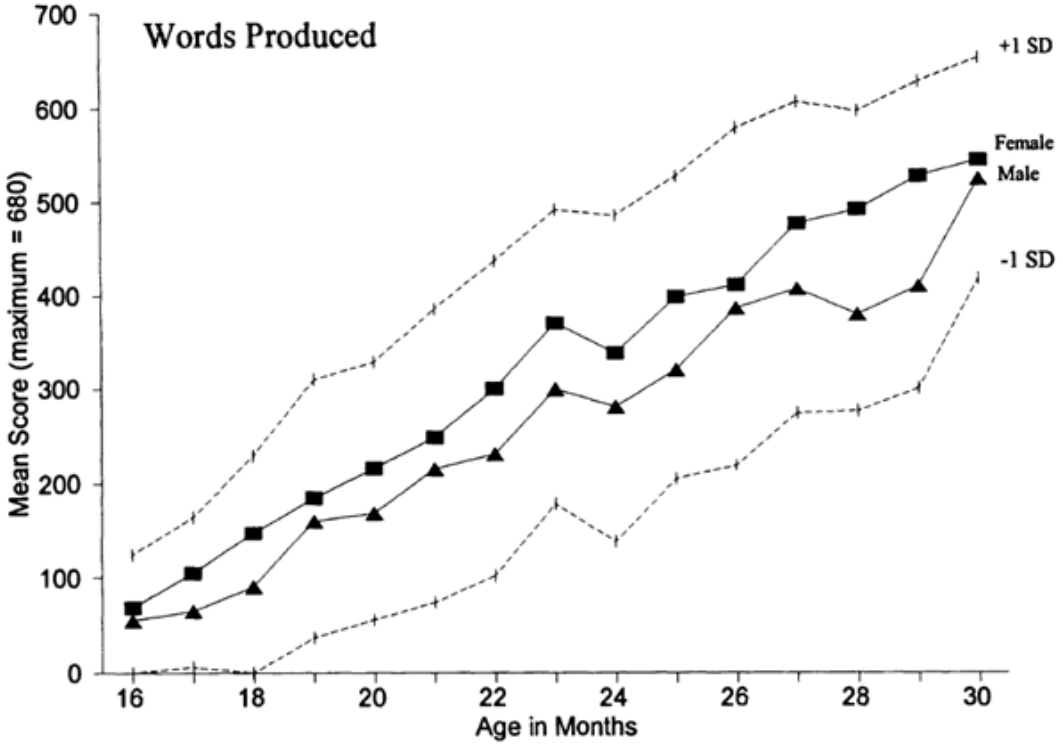
Figure 1: Cohen's d for various language tests (from Ref A1.12)



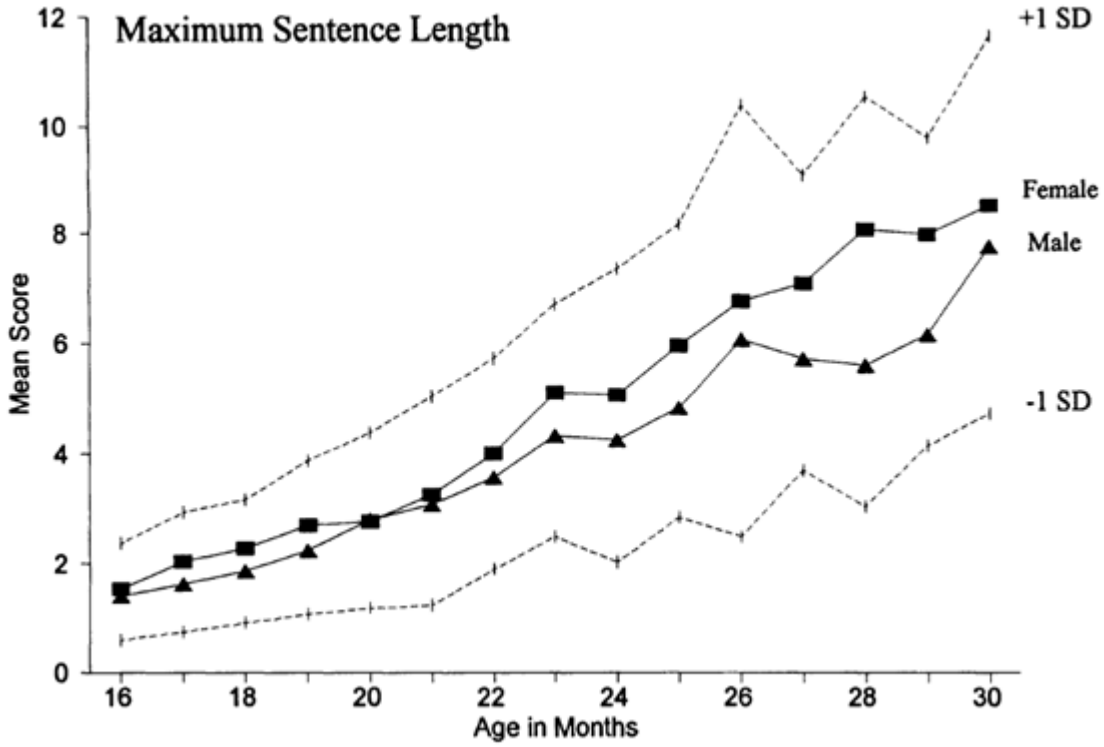
Notes: Positive values indicate a female advantage. Error bars show the 95%–CI of the effect size Cohen's *d*. Abbreviations on the x-axis: M = Mottier Test; KiSS.2: RW = repetition of non-words, RS = repetition of sentences, R = repetition of non-words and sentences, A = articulation, V = vocabulary,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

Figure 2: Male v Female Verbal Ability Scores versus Age (Ref.B1.1d, Figs26-28)

(a)



(b)



(c)

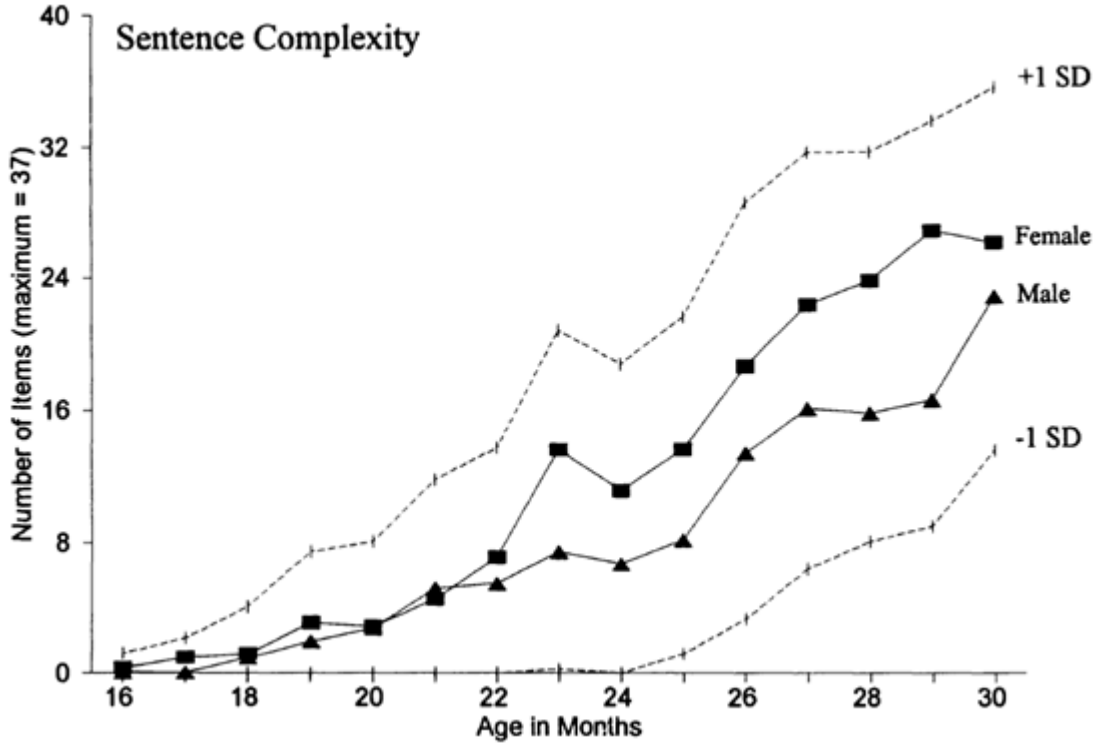


Table 2: Size of Sex Difference in Parental Speech

Ref.	Effect Size*	Effect Size Measure
A1.2a	1.20 [1.06,1.32]	Average of score ratios, 11 features
A1.2c	1.14	Ratio of initiatives to vocalise by a parent
A4.1a	0.22 – 0.29	Cohen's d, across 13 studies
A5.1	1.17 [1.07,1.27] (1)	Ratio of scores
A5.1	0.27 [0.07,0.46] (1)	Cohen's d

(1) *Over two measures and two ages*

Table 3: Measurements of Language Ability or Development and Their Correlates

Typ?: 'Norm' indicates the sample was typical of the general population; 'Atyp' indicates a sample with a known developmental issue, e.g., dyslexia, autism, etc. 'Both' indicates a mixed sample. **N** is the sample size. Where a sex difference was reported, (g) indicates the difference is to girls' advantage. This is case in all 18 studies listed in this Table.

Ref	Ages	Typ?	Sex difference?	N	Year	Main Findings
A1.9	3 years	Both	Yes (g)	639	2003	RCT study: Speech delay associated with maternal education, family history and being male (combined OR 7.7). Being male alone had OR of 2.19.
S1c	3 – 6 years	Norm	Yes (g)	10,000	2016	Tests were administered to assess the children's vocabulary, grammar, speech comprehension, pronunciation, and the processing of sentences and nonce words. Girls performed better than boys in all domains, most often to a statistically significant degree, although the effect sizes were small. Differences decreased with age. Boys varied significantly more than girls in their language competence. Effect diminished with age to age 6.
S1d	Meta-analysis 8 mths to 15 yrs	Norm	Yes (g)	3,657	2017	The effect sizes increased with children's increasing age. All significant effects proved to be in favour of girls.

S1e*	8 – 20 mths	Norm	Yes (g)	1,803	1994	Sex differences consistently favour females; however, these are very small, typically accounting for 1%-2% of the variance.
S1f	24 mths	Atyp	Yes (g)	1,766	2012	13.4% of general population are subject to Late Language Emergence (LLE). Risk for LLE at 24 months was not associated with parental educational, socioeconomics, parental mental health, parenting practices or family functioning. Significant predictors included familial history, male gender and early neurobiological growth.
S1g	10 – 11 yrs	Atyp	Yes (g)	1,605	2009	Dyslexia is 1.5 times more common in males than females
A1.11	2 – 5 yrs	Both	Yes (g)	?	2021	Between 5% and 12% of children ages 2 to 5 years are diagnosed with a speech or language delay. Fifty percent of these children experience delays that persist into adolescence and face educational and occupational challenges later in life. Risk factors include male sex.
A1.11a	Meta-analysis 745 studies Up to 5 yrs	Norm	Yes (g)	large	2006	Speech and language development … is related to school success. The most consistently reported risk factors for speech or language delay included a family history, male gender, and perinatal factors.
A1.12	4 yrs	Norm	Yes (g)	224	2021	Several tests were administered to assess articulation, vocabulary, grammar, speech comprehension, and, most importantly, phonological short-term memory (PSTM). Girls performed better than boys in all domains. Most importantly, evidence for a female advantage in PSTM

						performance was found. Analyses revealed that the observed sex differences in articulation, vocabulary, grammar, and comprehension were partially or fully mediated by (sex differences in) PSTM.
A1.13	12-30 mths	Norm	Yes (g)	230	2021	Vocabulary scores (receptive, expressive) correlate with age and the median for girls is higher until 24 months.
A1.14	?	Atyp	Yes (g)	4,632	2021	A cohort of patients with language, speech and learning disorders were studied. Of all the variables studied, only the incidence of delay in language development with respect to the male sex was significant; three out of four patients were male and 1 female.
B1.1	10 mths to 3 years 4 mths	Norm	Twins, Yes(g) Singletons, Yes(b)	97	2021	Twin children's early vocabulary shows sex differences – with boy twins having smaller vocabularies than age-comparable twin girls. (However, the singletons studied in this work did not show female advantage).
B1.1a	18 months	Norm	Yes (g)	1019	2005	The results demonstrate significant effects of gender and birth order on vocabulary comprehension and vocabulary production. Girls scored higher than boys and first-born children scored higher than later-born children. Gender was more important than birth order, or socioeconomics or childcare.

B1.1b	1 mth to 2 yrs	Norm	Yes (g)	13,783	2012	The results showed that girls are slightly ahead of boys in early communicative gestures, in productive vocabulary, and in combining words. The difference increased with age. Boys were not found to be more variable than girls. Despite extensive variation in language skills between language communities, the difference between girls and boys remained. This suggests that the difference is caused by robust factors that do not change between language communities.
B1.1c	Meta analysis 165 studies	Norm	Yes (g) but negligible	1,418,899	1988	The weighted mean effect size was +0.11, indicating a slight female superiority in performance. The paper claims that "the difference is so small that we argue that gender differences in verbal ability no longer exist". However, their results for speech production have a Cohen's d of 0.33 [0.20,0.46] which is a medium sized effect.
B1.1d	8 – 30 mths	Norm	Yes (g)	1,803	1994	Sex differences consistently favour females. Sex effect was larger than the effects of socioeconomics and birth order. The paper claims the sex effects "are very small, typically accounting for 1%-2% of the variance". However, Figs.26, 27, 28 suggest female:male score ratios on verbal tests at 30 months to be 1.15, 1.23 and 1.35 respectively.
B1.1e	3 to 5 years	Norm	Yes (g)	180	2002	Significant sex differences were found in syntactic development, with girls outperforming boys in mean

						utterance length, some sentence types and structures, and syntactic complexity. The period between age 3 and age 4 was identified as critical for syntactic development, as many linguistic changes occurred in this time. Growth in the ability to use compound sentences was found to be the most significant contributor to increased mean length of utterance.
A4.1	5 to 17 years	Both	Yes (g)	175	2015	In typically developing children and children with ASD (Autism), females (n = 47 and n = 15, respectively) were significantly superior in their ability to recognize words under audiovisual listening conditions compared to males (n = 55 and n = 58, respectively). This sex difference was absent in our sample of neurotypical adults (n = 28 females; n = 28 males). We propose that the development of audiovisual integration is delayed in male relative to female children, a delay that is also observed in ASD. In neurotypicals, these sex differences disappear in early adulthood when females approach their performance maximum and males "catch up."

**yellow highlight indicates the full text was not obtained and the Abstract only used. Full papers were obtained in all other cases.*

Table 4: Parents Speech Patterns to Children

N is the sample size. Where a sex difference was reported, (g) indicates the difference is to girls' advantage. This is case in 8 of the 11 studies listed here. "**Parent**" indicates the parent whose speech was studied (Mo=mother, Fa=father).

Ref	Ages	Parent	Sex difference?	N	Year	Main Findings
A1.1	8 – 28 months	Mo	No	30	1973	Mothers' speech to boys and girls found to be the same.
A1.2	6 – 14 months	Mo	Yes (g)	36	2006	Sex differences were found in mothers' verbal behaviour and level of engagement: more engaged with girls, less conversational with boys.
A1.2a	2 years	Mo	Yes (g)	12	1975	Mothers of female children talked more, asked more questions, repeated their children's utterances more often, and used longer utterances compared with mothers of male children.
A1.2b	9 – 15 months	Mo + Fa	9mths yes (b) 15 mths no	87	2002	Parents of boys vocalized more than parents of girls when the infants were 9 months of age. Boys and girls received similar amounts of vocal stimulation at 15 months.
A1.2c	6 months	Mo + Fa	Yes (g)	40	1988	Mothers showed a higher vocal activity than fathers. Girls received more vocal initiations from fathers than boys, while mothers treated boys and girls equally.
A1.2d	3 – 9 months	Mo + Fa	Yes (b) variable	72	1987	Both fathers and mothers of male infants had a higher proportion of explanations than parents of female infants,

						however for 'game statements' it could be the other way around.
A1.3	0,2,6,9,12 months	Mo	Yes (g)	12	2003	The study examined affective adjustments in speech as a function of infant age and sex. … mothers expressed more affection in speech to girls than boys.
B3.1	4, 8 & 12 months	Mo	Yes (g)	87	2002	Unusually this was a longitudinal study (predicting speech at 12 months from earlier behaviours). For a range of independent variables, gender was the dominant regression coefficient – i.e., more important than variables associated with mother's speech etc. Maternal verbal encouragement of attention appears to be particularly salient in the development of language for boys.
A4.1a	Meta analysis 13 studies	Mo + Fa	Yes (g)	545	1998	Across studies, mothers tended to talk more (d = .26), use more supportive (d = .23) and negative (d = .13) speech, and use less directive (d = .19) and informing (d = .15) speech than did fathers. Also, mothers tended to talk more (d = .29) and use more supportive speech (d = .22) with daughters than with sons.
A5.1	19 & 24 months	Mo + Fa	Yes (g)	57	2011	Both fathers and mothers used a larger mean number of words and a larger mean length of utterances (MLUs) when speaking to girls than when speaking to boys. This was true at both ages studied.

A5.2	3 – 11 months	Mo	No	30	2013	Mixed picture with evidence of greater maternal speech response to girls or to boys depending on age and the measure used. Quote, "The fact that the patterns of infant vocalization and maternal speech parallel one another does not tell us whether infants vocalize more in response to maternal vocalization or vice versa."

Table 5: Neurobiological, Genetic or Endocrine Evidence of Sex Differences Relevant to Infant Speech
Typ?: 'Norm' indicates the sample was typical of the general population; 'Atyp' indicates a sample with a known developmental issue, e.g., dyslexia, autism, etc. 'Both' indicates a mixed sample. **N** is the sample size. Where a sex difference was reported, (g) indicates the difference is to girls' advantage. This is case in all 11 studies listed here.

Ref	Ages	Typ?	Sex difference?	Year	Main Findings
A1.6	adults	Norm	Yes	1983	It is concluded that there are sex differences in the organization of speech and praxis within the left hemisphere and that speech is not simply more bilaterally organized in females than males. See Appendix for details.
A1.7	9 and >13 years	Norm	Yes	1983	Boys and girls both show left-hemisphere specialization for speech in early childhood. However, by late childhood the adult pattern of greater language lateralization in males than in females is established.
A1.8	10 – 16 years	Norm	Yes but as surrogate for later maturation	1976	Regardless of sex, early maturing adolescents performed better on tests of verbal than spatial abilities, the late maturing ones showed the opposite pattern. Those maturing late were more lateralized for speech than those maturing early. Sex differences in mental abilities, it is argued, reflect differences in the organization of cortical function that are related to differential rates of physical maturation.
A1.10	Meta analysis	Norm	Yes	1980	Reviews evidence and finds "impressive" that the male brain is more asymmetrically organised than the female brain, for both verbal and non-verbal functions, but this applies in the "mature organism" whilst being rarely found in childhood.

S1	Review paper, all ages	Both	Yes	2019	Girls have a well-documented advantage in early language development, and almost all developmental disorders primarily affecting communication, speech, and language skills are more frequent in boys. It is argued that the functional organization of the female brain gives women an inherent advantage in the acquisition of communication and language system over men.
S1a	Meta-analysis	Both	Complicated Not clear	2018	This paper is difficult to summarise. Overall, they report finding inconsistent evidence for sexual dimorphism in language and brain development. Quote, "Evidence for significant sex differences in brain structure and function is limited, and research to date related to this topic has resulted in conflicting reports". On the other hand, in their review of Schmidhorst and Holland (2007) they conclude, "Due to the large number of subjects and rigorous correction for multiple comparisons, these results provide strong evidence of sex differences in brain function supporting language comprehension in children". However, the Supplementary Material usefully lists many differences reported by other studies (see the Appendix for details).
A2.1	Review Primary school age, to 11	Atyp		2019	Structural brain differences by sex related to different rates and symptomatology of dyslexia in girls & boys – see Figure 3, below.
A3.1	Review	Both	Yes (g)	2017	The paper argues that boys are "at risk". Significant gender differences are seen between male and female social and emotional functions in the earliest stages of development, and that these result from not only

					differences in sex hormones and social experiences but also in rates of male and female brain maturation, specifically in the early developing right brain.
A5.1a	4 weeks	Norm	Yes (g)	2008	Using a phonological discrimination paradigm, we show that the brain responses of 4-week-old infants systematically vary as a function of biological sex and testosterone level. Females who are generally low on testosterone demonstrated a clear phonological discrimination effect with a bilateral distribution. In male infants this effect systematically varied as a function of testosterone level. Males with high testosterone showed no discrimination effect, whereas males with low testosterone displayed a discrimination effect, which was clearly left-lateralized. The present data provide evidence for a strong influence of testosterone on language function and lateralization already present during the first weeks of life.
A5.1b	2 mths to 16 yrs	Norm	Yes (g)	1999	Differences in gender-specific rhythms were statistically significant in brain regions paired with frontal and temporal cortices. From birth to age 6 years, girls exhibited synchronized EEG coherence peaks in cortical regions known to be associated primarily with concurrent discrimination, language processing, fine motor skills, and social cognition. During this same early period, boys exhibited synchronized EEG coherence peaks in cortical regions known to be associated primarily with spatial-visual discrimination and executive planning related to gross motor movement, visual targeting, and accessing stored information.

Figure 3: Schematic Illustration of Effects of Foetal Testosterone and Grey Matter Volume (from Ref. A2.1)

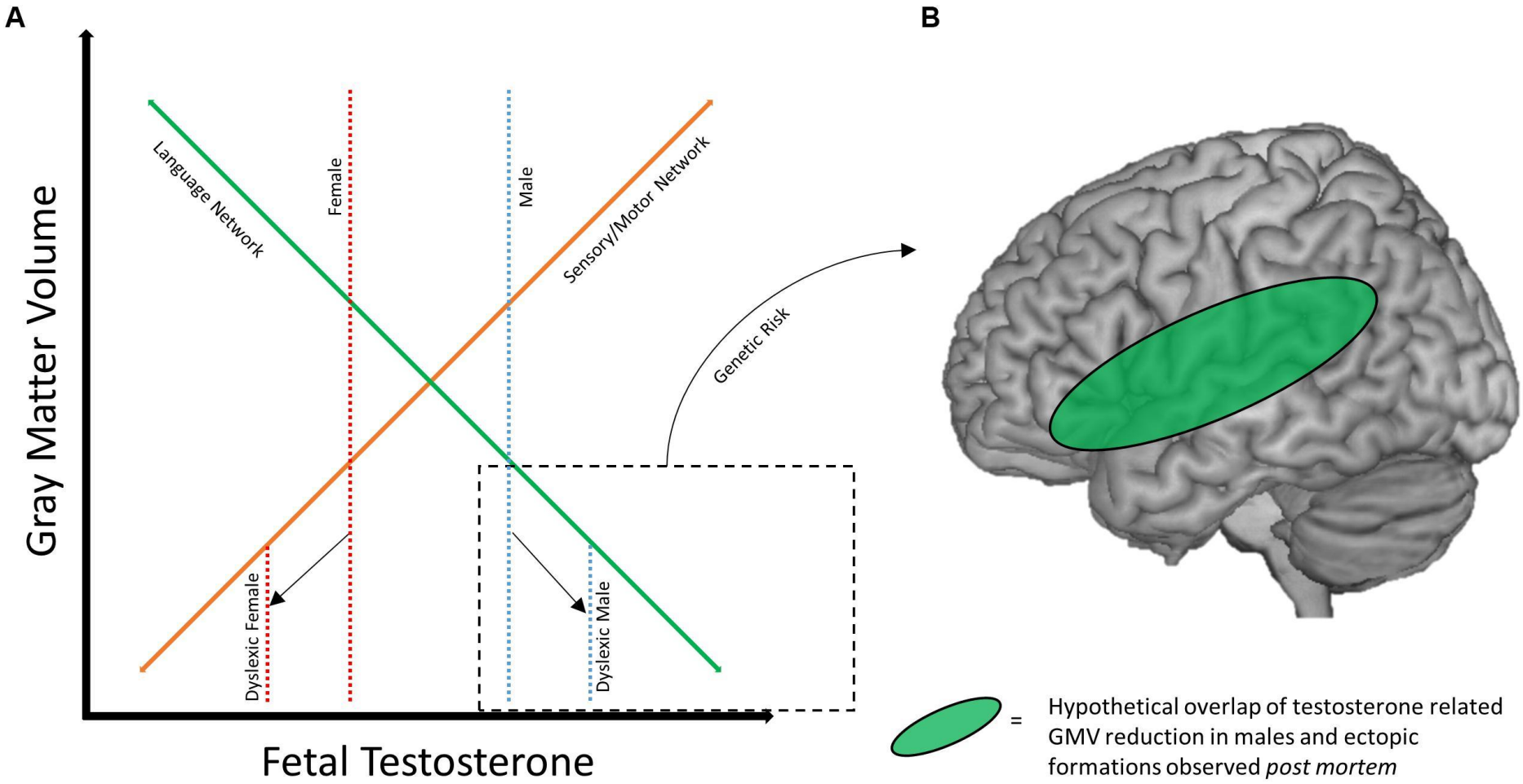


Table 6: Sex Differences in Brain Structure (from Supplementary Material of Ref.S1a)

Observed Differences	**Possible Implications**	**Age years**
Males had greater absolute volume in several regions throughout the cerebrum. Females had larger caudate and cerebellar vermis in females when normalized for total brain volume.	Relevant for ADHD and stuttering.	0 - 5
When controlling for intracranial volume, the left hippocampus was larger in boys than in girls.	Volume predicted receptive language in females. Expressive language scores were greater in children with a larger left hippocamapus.	0 - 5
Sex did not affect brain size at birth but later there were large structures in boys relative to girls.		0 - 5
Myelin water content was higher in girls whereas the growth rates were significantly higher in boys.	Receptive language scores were correlated with myelin water fraction in the cerebellum, thalamus and occipital white matter.	0 - 5
Girls' brains are typically 93% of the volume of boys' brains. Relative to brain size, the caudate, hippocampus and pallidum are larger and the amygdala is smaller in girls than boys brains.		9
Boys brains were 7% larger than girls brain. Controlling for total brain volume, girls had larger mesial and lateral temporal lobe volumes, and larger thalamus and caudate than boys.		7 - 16
Brain volume was 9% larger in boys than girls. The basal ganglia were larger in females even when adjusted for height and weight. No other structures exhibited sexual dimorphism in brain size.		4- 18
The corpus callosum has a non-linear developmental trajectory that is dependent on age and sex. Relative to total brain size, the ratio of the corpus callosum, genu, posterior midbody and splenium is higher in girls than boys. Females reached local maximum in the corpus		0 - 25

callosum around 16 years whereas males reached maximum at around 17 years.		
Sex differences were age dependent and follow a nonlinear developmental trajectory. Total cerebral volume peaks at 10.5 in males and 14.5 in females. Gray matter volumes peak 1-2 years earlier in girls than boys and is likely associated with pubertal maturation.		3 - 27
Boys had higher fractional anisotropy (FA) than girls in the multiple left hemisphere association fibers. Girls had higher mean diffusivity (MD), axial diffusivity (AD), and radial diffusivity (RD). Results suggest that boys (13–18 years) continued to demonstrate white matter maturation, whereas girls appeared to reach mature levels earlier. The preliminary evidence presented in this study supports that boys and girls have different developmental trajectories in white matter microstructure.	Authors identified significant positive correlations between FA and full-scale intelligence quotient (IQ) in the right inferior fronto-occipital fasciculus when both sexes were looked at together. Only girls showed significant positive correlations between FA and verbal IQ in the left cortico-spinal tract and superior longitudinal fasciculus.	15 - 18
Girls have a stronger leftward asymmetry of the planum temporale (smaller right planum temporale) regardless of age.	The significance is unknown but the authors suggest it may relate to preparing the brain for language development.	3 - 14
Direct statistical contrasts between males and females suggested age dependent sex differences in covariance networks associated with speech production (inferior frontal gyrus (IFG) and Heschls gyrus). In early and late adolescence, girls showed greater covariance in the right insula and left IFG. With respect to auditory processing, males in early and late childhood showed greater covariance in the right insula. Females in late childhood and adolescence had greater covariance in the right supramarginal and superior temporal gyrus. Sex differences are dependent on age but should be interpreted with caution.	Speech production	5 - 18

Boys had more prominent age related gray matter decreases and white matter and colossal increases compared with girls suggesting there are age related sex differences in brain maturation		7 - 17
Boys exhibited greater variability in volume of the left cerebrum, and superior temporal gyrus and girls exhibited greater variability in the right caudate and right putamen.		4 - 20
Girls had greater FA in the splenium of the corpus callosum than boys. Boys had greater FA in the bilateral frontal regions, right arcuate fasciculus and left parietal lobes. There were also significant age and sex interactions with girls having a greater rate of increase of fiber density (mean diffusivity) compare to boys		12
Females develop earlier in most tracts as reflected by a reduction in radial diffusivity. The exception was the right superior longitudinal fasciculus which also matured early in males. Developmental trajectories of white matter characteristics differed by sex and depended on age group, puberty group and region. Listed p values show most results were actually non significant (with the exception of the internal capsule and the anterior thalamic radiation).		8 - 33
Boys had a larger amygdala and girls had a larger caudate. Boys had more global gray and white matter than girls. Both sexes exhibited high variability in gray matter ROIs. Some laterality effects were evident in the cingulate, occipital and temporal lobe. Locally, girls had a larger caudate, cingulate and IFG while boys had higher volumes in posterior temporal and insula.		5 - 18
The superior temporal asymmetrical pit (STAP) is present in 95% of humans irrespective of handedness and language lateralization. The STAP is larger in males than in females, likely as a result of larger brains. Functional significance is unclear.		0 - 22

Total cerebral volume, Grey Matter and White Matter was larger in males. Males have larger left inferior frontal gyrus and greater white matter asymmetry even when controlling for total cerebral volume. Boys also demonstrated significant age-related volumetric increase in the IFG, while girls did not.		6 - 17
Widespread sexually dimorphic trajectories in structural white matter development were observed. Females had more advanced development indicated by lower mean diffusivity, radial and axial diffusivity, and higher FA. Difference was larger at younger years. (8–9 years) with diffusion measures from males and females tending to converge between 10 and 14 years of age. Males showed a steeper slope for age-diffusion metric correlations compared to females, who either did not correlate with age or correlated in fewer regions.		8 - 16
Boys showed greater activation the girls in the right anterior singulate and superior frontal gyrus.	Children with higher vocabulary scores showed increased lateralization of gray matter in the bilateral thalamus, hippocampus and left angular gyrus.	3 - 5
	For (fMRI) activation data, sex differences were documented for three out of four language tasks. When sex differences were detected, they interacted with age and task and were relatively small in magnitude.	5 - 18
Girls showed higher values in path length but lower values on global efficiency than boys. There were sex differences in the default mode network and in language networks (including IFG, putamen). Also sex differences in visuospatial regions (e.g. cuneus).		6 - 18
Girls were more accurate than boys in all conditions. Interhemispheric connection was stronger in girls than boys and stronger from right STG to left STG than in the opposite direction.	This was associated with slower performance and low verbal IQ in girls, suggesting that excessive	9 - 15

	connectivity between hemispheres interferes with phonological tasks.	
Girls had stronger activation in the inferior frontal and superior temporal regions.	Activation of the left inferior frontal gyrus was correlated with linguistic accuracy for girls regardless of modality of the stimulus. For boys accuracy depended on stimulus modality. Suggests that girls rely on a more supramodal network and boys process modalities differently.	9 - 15
There is a shift within the extrastriate cortex in boys that is associated with visual language performance, and similarly a lateral shift in the fusiform gyrus that is associated with accurate visual language performance in girls.	Suggests different patterns of connectivity in Ventral Visual Pathway to achieve similar performance.	9 - 15
Girls had higher amplitudes of auditory evoked responses in the left hemisphere and boys has higher responses in the right hemisphere suggesting existence of sex differences in language and spatial functions		10weeks 13weeks
In males but not females, topography in the right hemisphere differentiated between known and unknown words whereas in the left hemisphere it was only activity in the left hemisphere.		16 month
From birth to age 6 girls exhibited peaks in cortical regions associated with language, fine motor movement social cognition while boys exhibited peaks in areas associated with visuospatial processing, and gross movement.		2 month - 16 years
More slow wave activity in females than males. Males show increased slow wave activity over the right prefrontal cortex relative to females, a region associated with spatial abilities. Girls show larger cortical thickness in language but not frontal regions. Interestingly, larger activation of language areas was correlated with better language skills.		9 - 19

Simple linguistic processing that requires distributed bilateral activation elicited a similar pattern in in both groups, but more complex tasks tend to elicit subtle differences between the groups. Girls exhibited more right lateralized activation during phonological task. No behavioral differences in linguistic function suggesting brains are equally efficient.		10
Boys showed left lateralization of gamma band activity in frontal and temporal regions in early childhood. Girls showed a more bilateral distribution of activity that became left lateralized at around the age of 16.	No differences in language ability between the sexes.	4 - 18
Neural responses to a familiar voice (mothers voice) was significantly lower in older girls as compared to older boys in the left hemisphere only. No differences were observed in the younger group.		3 - 6