

Factors associated with receptive and expressive language in autistic children and siblings: A systematic review

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Abstract

Background & aims: Language abilities of autistic children and children at elevated likelihood for autism (EL-siblings) are highly heterogeneous, and many of them develop language deficits. It is as of yet unclear why language abilities of autistic children and EL-siblings vary, although an interaction of multiple influential factors is likely at play. In this review, we describe research articles that identify one or multiple of such factors associated with the receptive or expressive language abilities of autistic children and EL-siblings since the introduction of the *DSM-5*. Our aim was to identify and summarize factors that are linked to language development in autistic children and siblings in the recent literature to ultimately gain insight into the heterogeneity of language abilities in these children.

Methods: The search strategy of this review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. The following databases were consulted: Embase, MEDLINE, Web of Science Core Collection, and Scopus. Inclusion criteria for studies were the presence of a sample of autistic children no older than 7 years old who were diagnosed with autism spectrum disorder per the criteria of the *DSM-5*. Intervention studies and studies without an explicitly reported language measure were excluded. Risk of bias assessment was completed using the Newcastle–Ottawa Scales. Ultimately, 55 articles were included in this review.

Main contribution: Fifty-six factors were identified to be related to receptive or expressive language abilities of autistic children and EL-siblings. They were grouped into three main categories: biological factors; psychosocial and environmental factors; and age-related and developmental factors, each with different subcategories. Although many of the identified variables were only examined in one article, some well-researched associated factors were reported across multiple studies and were present in both autistic children and EL-siblings, in particular joint attention, nonverbal cognitive abilities and frontal EEG power. Better insight in these factors associated with language abilities in autistic children and siblings at elevated likelihood can inform future intervention strategies to reduce language deficits and its corresponding negative consequences in these children.

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Conclusions: Our results confirm that multiple different factors likely underlie language deficits in autism. Important aspects that should be considered are, among others, social factors such as joint attention, child characteristics such as nonverbal cognition, and neurocognitive factors.

Keywords

Autism, young children, siblings, receptive language, expressive language, systematic review

Introduction

Language abilities are highly heterogeneous in children with autism spectrum disorder (henceforth autism) (e.g., Baird & Norbury, 2016; Kjelgaard & Tager-Flusberg, 2001; Pickles et al., 2014), a neurodevelopmental condition characterized by challenges in social communication and social interaction, and restricted and repetitive behaviors (American Psychiatric Association, 2013). Apart from the pragmatic aspect of language involved in social communication which is inherently difficult for autistic children (e.g., Eigsti et al., 2011; Ellawadi & Ellis Weismer, 2015; Kelley et al., 2006), some of these children also experience structural language difficulties (Boucher, 2012; Eigsti et al., 2011). A typical language profile that has previously been observed in school-aged autistic children is relatively intact phonetic and syntactic (grammar) abilities, yet impaired semantics and morphology (e.g., Bartolucci et al., 1980; Boucher, 2012; Roberts et al., 2004; Tager-Flusberg et al., 2005). It should however be noted that even language skills generally considered intact appear to be differentially impaired in autistic populations (Modyanova et al., 2017; Reindal et al., 2021; Wittke et al., 2017). For example, Reindal et al. (2021) demonstrated that 27% of their sample of autistic children between 4 and 18 years old attained clinical scores on the syntax subscale of the Children's Communication Checklist-2 (CCC-2) (Bishop, 2003). Additionally, autistic children, on average, produce less complicated sentences and wh-questions (e.g., questions with "who," "where," "what," etc.) compared to their neurotypical peers, and sometimes struggle with reflexive pronouns (e.g., "himself") (Cantwell et al., 1978; Eigsti et al., 2007; Perovic et al., 2013).

Language deficits are not only prevalent in autistic children but also in siblings with an elevated familial likelihood to develop autism (henceforth EL-siblings). Autism is highly heritable (Colvert et al., 2015) and the recurrence rate for siblings of autistic children is close to 20% (Ozonoff et al., 2011). EL-siblings are therefore an often-studied population to examine early markers for autism, such as impaired language, even before the age a diagnosis can reliably be made. When siblings at elevated likelihood are as young as six months old, some parents already express their first concerns about their child's language development, regardless of whether the child eventually receives a clinical diagnosis of autism (Talbot et al., 2015). Additionally, a recent meta-analysis showed that even EL-siblings who did not receive an autism diagnosis were still

three to four times more likely to exhibit language deficits or delays compared to siblings of neurotypical children (Marrus et al., 2018), indicating that early delays in language may be an important behavioral endophenotype for autism.

While some studies have argued that language comprehension (receptive language) is more impaired than language production (expressive language) in autistic children and EL-siblings (Charman et al., 2003; Hudry et al., 2010; Kjelgaard & Tager-Flusberg, 2001; Özyurt & Dinsever Eliküçük, 2018), a recent meta-analysis showed that, on average, receptive and expressive language are equally impaired, although individual differences are present (Kwok et al., 2015).

Importantly, despite an ongoing debate about the similarities and differences between autism and developmental language disorder (see e.g., Bishop, 2010; Georgiou & Spanoudis, 2021; Kjelgaard & Tager-Flusberg, 2001), the language deficits and their underlying processes present in autistic persons cannot plainly be assumed identical to those in persons with a developmental language disorder (Luyster et al., 2011; Özyurt & Dinsever Eliküçük, 2018; Pickles et al., 2009; Tager-Flusberg et al., 2005; Whitehouse et al., 2008; Williams et al., 2008). Hence, language deficits of autistic children and EL-siblings cannot fully be explained by a comorbid developmental language disorder.

It remains unclear what does cause the heterogeneity of language abilities in autism. Many studies have investigated single factors that may be linked to language development in autistic children and EL-siblings, such as motor skills (e.g., Choi et al., 2018; Wu et al., 2021), or parental language input (e.g., Bang & Nadig, 2015; Flippin & Watson, 2015), but it seems clear that no single factor alone can explain this heterogeneity, and likely an interaction of multiple factors, that is, genes, brain, behavior, and environmental factors, is at play (Pennington, 2006; Tager-Flusberg, 2016).

Better understanding of the heterogeneous pathways associated with language abilities of autistic children and EL-siblings is crucial as language level, together with IQ, is one of the best-known predictors of post-childhood short- and long-term developmental outcome (Billstedt et al., 2007; DeMyer et al., 1973; Howlin et al., 2004; Kover et al., 2016; Magiati et al., 2014; Mayo et al., 2013; Paul & Cohen, 1984; Sevaslidou et al., 2019). Conversely, language difficulties in childhood are associated with negative emotions (Sturrock et al., 2022), and low levels of functional ability in later life for autistic individuals (Howlin et al., 2013).

This systematic review therefore aims to identify and summarize recent articles examining factors associated with receptive and expressive language development of autistic children and EL-siblings. The concept of “autism spectrum disorder” has only been formally introduced in the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders (DSM-5)* (American Psychiatric Association, 2013), and diagnostic categories and criteria have changed compared to the criteria for the pervasive developmental disorders (PDDs) in the previous versions in the DSM (*DSM-IV-TR*) (American Psychiatric Association, 2000). Notably, references to atypical language development in diagnostic criteria present in the *DSM-IV-TR* have been omitted in the *DSM-5*, in which a comorbid developmental language disorder can be added as a specifier to the diagnosis. Research has shown that while 50–75% of people will maintain their diagnosis, fewer individuals meet the *DSM-5* diagnostic criteria than the *DSM-IV-TR*, indicating that some children who were once identified with a PDD, especially those classified as PDD-NOS (not otherwise specified) and Asperger’s (Smith et al., 2015), would not receive an autism spectrum diagnosis now (Peters & Matson, 2020; Rieske et al., 2015; Wiggins et al., 2019). Moreover, younger children are more likely to meet *DSM-IV-TR* criteria than older children, while this age effect is not present for the *DSM-5* criteria (Peters & Matson, 2020). It is thus conceivable that some children diagnosed with *DSM-IV-TR* criteria do not fulfill current criteria for an autism spectrum disorder diagnosis. This makes a comparison of language abilities of children diagnosed based on differing diagnostic criteria between *DSM-IV-TR* and *DSM-5* complicated.

Moreover, the goal of this review is to provide an overview of the current state of the field. Thus, to ensure that results of this review consider only the most recent findings and that they do not reflect different diagnostic definitions (Peters & Matson, 2020), only studies published in or after 2013 and applying diagnostic criteria for “autism spectrum disorder” as specified by the *DSM-5* will be considered, or studies including siblings at an elevated likelihood for this condition in or after 2013 as any future diagnostic process in these children will most likely follow *DSM-5* criteria.

A narrative review of factors related to language abilities in EL-siblings has already been published (Tager-Flusberg, 2016). In this narrative review, the author concludes that no single factor seems uniquely related to language in autism, but instead a multifactorial, complex model of risk may better explain individual variance and more research is needed to further uncover individual clusters of risk markers (Tager-Flusberg, 2016). A systematic review that considers recent literature (since the formal introduction of the autism spectrum in the *DSM-5*) on factors associated with language abilities in autistic children and EL-siblings has not yet been conducted. Identifying factors that may be linked to language development in autistic children and EL-siblings may ultimately shed more light on the heterogeneity of language abilities in these children. This can in turn inform future intervention

strategies to reduce language deficits and its corresponding negative consequences.

Method

This literature review was preregistered on Prospero (ID: CRD42021271264) in August 2021 and was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021).

Literature search

A comprehensive literature search to identify relevant articles was conducted on August 1 and 2, 2021, and complemented by a final search close to the submission date on June 3, 2022. The search was limited to studies published in or after May 2013, when the *DSM-5* was introduced.

The online search was performed in Embase, MEDLINE, Web of Science Core Collection, and Scopus. Within each database, keywords and subject headings pertaining to the following three broad concepts were used: (i) autism spectrum disorder; (ii) language development; and (iii) pediatric sample. The terms in each category were included within parentheses using the Boolean operator “OR,” and the resulting four brackets were connected by “AND.” An overview of the specific terms used per database can be found in the search strategy in the supplemental information.

Inclusion and exclusion criteria

After the removal of duplicates, articles identified by the literature search were required to meet preestablished criteria to confirm their relevance. The inclusion and exclusion criteria were defined as follows:

- Records could include retrospective, cross-sectional or prospective investigations;
- Records needed to one-directionally examine one or more factors that were associated with receptive or expressive language skills in autism. This means that records were included if their research question included some form of expressive or receptive “language skills” as the dependent variable, even if the statistical analyses did not express this one-directionality (i.e., correlation analysis). Records were not included if language skills were not considered to be the dependent variable;
- Participants were required to have an “autism spectrum disorder” diagnosis per *DSM-5* criteria or had to be at an elevated likelihood for autism (EL-siblings), regardless of diagnostic status;
- The average age of participants in included records did not exceed 6 years and 11 months, when it can reasonably be expected that a child without notable developmental difficulties has mastered all milestones of their

mother tongue. Moreover, variability in language skill in autism is at its greatest during this age, making it the ideal window into the early language heterogeneity and the factors associated with it (Pickles et al., 2014);

- The language measure used to characterize language abilities had to be reported explicitly. If this was not reported or if no language assessment took place, studies were excluded;
- Records reporting the results of an intervention method were excluded;
- Records focusing exclusively on second language acquisition and bilingualism were excluded;
- Abstract-only papers (e.g., proceeding papers, conference, editorial, and author response papers) were excluded;
- Records were required to be published in English and in peer-reviewed journals;
- Records without available full text were excluded.

Search selection

An initial screening of records based on title and/or abstract took place by two independent reviewers (MM and SS). Records were included in a second screening if the title

and abstract indicated that the article examined factors associated with receptive and/or expressive language abilities in autistic children and/or EL-siblings. Hereafter, full texts were evaluated to check the inclusion and exclusion criteria. First, the reviewers examined the method section of each paper to confirm a diagnosis per *DSM-5* criteria or elevated likelihood and the age cutoff for participants. Then the other in- and exclusion criteria were assessed one by one. Reasons for exclusion are summarized in Figure 1. Note that some articles did not fulfill multiple criteria. In that case, the article was excluded based on the first unfulfilled criterion that the reviewers came across. In the case of uncertainty about inclusion, the reviewers discussed the article and subsequently confirmed eligibility together. If it remained unclear if a record fulfilled the criteria, record authors were contacted for further clarification.

The electronic search was complemented by manually checking reference lists of included studies (backward chaining) and subsequent studies that cited the included papers (forward and backward chaining) on December 18 and 19, 2021. For a schematic overview of the review process, see Figure 1.

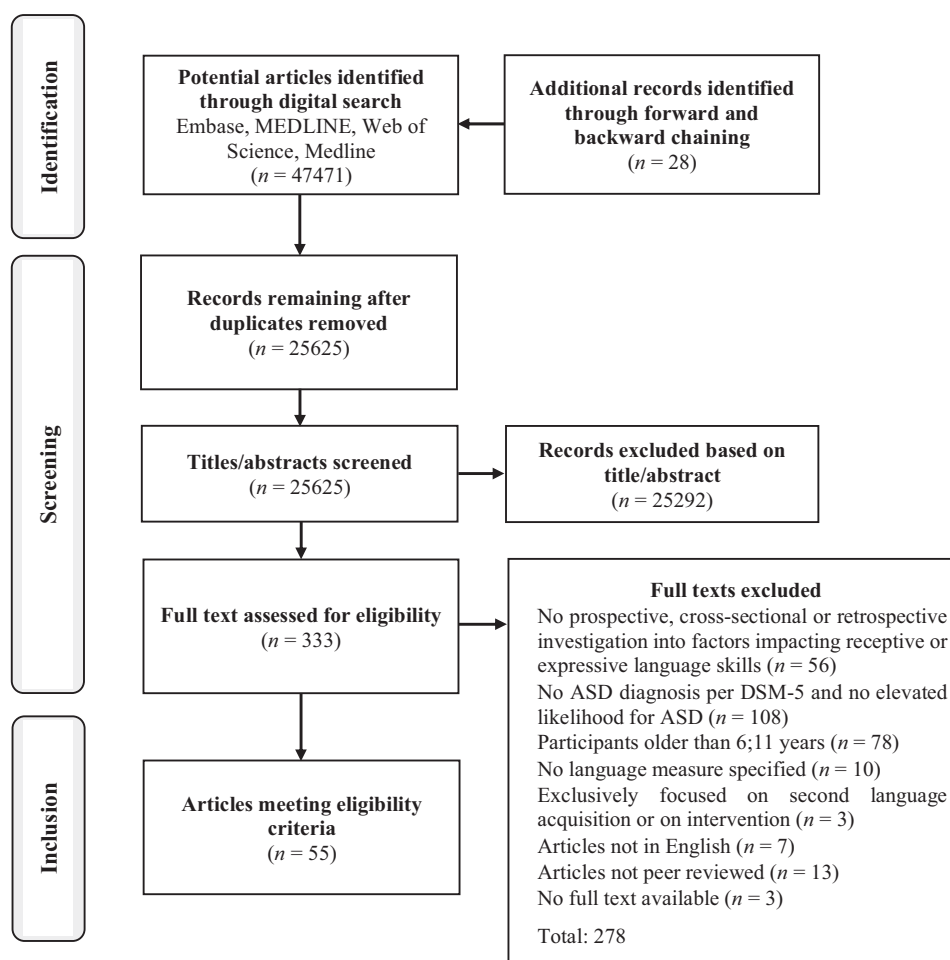


Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.

Data extraction

Of selected studies, crucial information was extracted of the overall sample and the sample per group if control groups were included. Information pertaining to sample size, average age of participants, gender ratio, and socioeconomic status were collected as well as the main results of the study and the methods used, such as the operationalization of language skills. The first and second authors independently extracted data from included reports and discussed the data in the case of uncertainty. This was the case for seven articles and was resolved among the authors for five of the articles. In the remaining two cases, the authors of the articles were contacted. Based on the information obtained from the authors, one of the articles was consequently included in the review (Saul & Norbury, 2020) while the other was not. The detailed coding manual may be requested from the first author.

Results

Study characteristics

A total of 55 articles drawing from 40 separate research studies were included in the systematic review (total study sample $n = 3244$ with autism, n siblings = 1379, 26% of the total study sample was female; sample size range = 8–1300; age range = 12.00–71.85 months at the time of language assessment). A summary of the mean and median publication dates is shown in Table 1.

Fifteen studies used a cross-sectional design, the remaining 25 studies employed a prospective research design; 24 studies examined autistic children, 16 investigated EL-siblings. Some studies followed-up EL-siblings to the age at that diagnostic assessment was possible, in which case this information is provided. One study included minimally verbal autistic children (Saul & Norbury, 2020). In studies that provided information about SES and race, most participants were higher middle class and white.

A majority of 30 out of 40 studies (75%) exclusively included monolingual English-speaking children. Languages that were investigated in the remaining ten studies were Cantonese Chinese (Song & So, 2022), Catalan (Torras-Mañá et al., 2016), Dutch (Bruyneel et al., 2019a; Bruyneel et al., 2019b), French (Bang & Nadig, 2015), Italian (Riva et al., 2018), Korean (Kim et al., 2020), Mandarin Chinese (Chen et al., 2021; Li et al., 2021; Wu et al., 2021), Spanish (Torras-Mañá et al., 2016), and Turkish (Okcun-Akcamus et al., 2019; Şengül et al., 2021).

Table 1. Summary of first (online) publication dates of included studies after acceptance.

	Mean	Median	Range
Date of publication	June 05, 2019	January 15, 2020	April 01, 2013–June 03, 2022

Language abilities

The expressive and receptive subscales of the Mullen Scales of Early Learning (Mullen, 1995), a standardized test of cognitive functioning, were most commonly used to characterize language abilities in included studies ($n = 20$ (50%)). Raw scores rather than standardized scores were often used in order to attain more variation in the data, since a floor-effect was frequently observed for autistic children and EL-siblings. Two other frequently used measures were the MacArthur-Bates Communicative Development Questionnaire (Fenson, 2007), a parent-reported instrument to capture early language development ($n = 16$ (40%)) and the Vineland Adaptive Behavior Scales, third edition (Sparrow et al., 2016), a tool to investigate children's everyday adaptive functioning ($n = 6$ (15%)). Many of the included studies included multiple language assessments.

Twenty-two of the 54 included articles compared the language abilities of autistic children or EL-siblings with a neurotypical control group. Most of these articles ($n = 17$ (77%)) showed that autistic children and EL-siblings scored significantly lower on at least one of the employed language measures: one article showed lower general language abilities for EL-siblings without distinguishing between receptive and expressive language (Wilkinson et al., 2020), two articles showed lower scores for EL-siblings only for receptive language (Chawarska et al., 2022; Choi et al., 2021a), three articles revealed lower scores for autistic children or EL-siblings only for expressive language (Choi et al., 2018; Droucker et al., 2013; Levin et al., 2017) and 11 articles observed both lower receptive and expressive language abilities for autistic children or EL-siblings (Bruyneel et al., 2019a; Bruyneel et al., 2019b; Choi et al., 2020a; Habayeb et al., 2020; Kyvelidou et al., 2021; Olson et al., 2021; Romeo et al., 2021; Tran et al., 2021; Wagner et al., 2018; Wilkinson et al., 2019; Wu et al., 2021). The remaining five articles did not identify group differences (Bang & Nadig, 2015; Edmunds et al., 2017; Flippin & Watson, 2015; Northrup & Iverson, 2015; Talbott et al., 2013).

Factors implicated in language

In our discussion of the literature below, we only include significant results derived from the included articles. Some articles may also include nonsignificant results when examining more than one factor associated with language. These nonsignificant results are not discussed here since we did not include articles with *only* nonsignificant results and therefore providing this information would lead to a skewed overview of the literature. These results are however discussed in Table 1 of the appendix where all results are summarized. Additionally, some articles may include multiple language measures in their examination. If conflicting results exist between the different language measures (i.e., one is significant and one is not), these results will be reported in the main text, in Table 2 and in Table 1 of the appendix.

Table 2. Summary of factors significantly associated with receptive and/or expressive language in autistic children or EL-siblings.

	Receptive language	Expressive language	General language abilities
Biological factors			
<i>Brain-based factors</i>			
Cortical reactivity	I SIB (115)		
Fractional anisotropy in the inferior longitudinal fasciculus	I ASD (104)	I ASD (104)	
Frontal delta power			I SIB (72)
Frontal high-alpha power		I SIB (25)	
Frontal theta power			I SIB (72)
Gamma power	I NOT (58)	3 SIB (72)	
Left frontal-central alpha coherence		I SIB (36)	
Neural correlates of face processing	I SIB (65)	I SIB (65)	
P3 peak latency		I SIB (39)	
Speech processing		I SIB (27), I NOT (14)	
Surface area left rostral middle frontal gyrus			I ASD (29)
Speech evoked auditory brainstem response			I ASD (29)
Temporal gamma power		I SIB (22)	
<i>Other biological factors</i>			
Biological sex			2 ASD (253)
Psychosocial and environmental factors			
<i>Autism traits</i>			
Hyporeactivity to sensory stimuli			I SIB (83)
Restricted and repetitive behaviors	I SIB (31), I NOT (104)		
Severity of social communication impairments	I ASD (113), I SIB (31), I NOT (104)	I ASD (113), I NOT (104)	
<i>Environmental factors</i>			
Maternal education*	I ASD (62)	I ASD (62)	
Mother rigidity (Broader Autism Phenotype (BAP) characteristics			I ASD (16)
Serum folate levels			I ASD (1300)
<i>Parental language input</i>			
Maternal gesture use			I SIB (48)
Maternal mean length of utterance	I SIB (22)	I ASD (19), I SIB (40)	
Parent verbal responsiveness			I SIB (83)
Paternal verbal responsiveness			I ASD (16)
Parental gesture quantity		I SIB (42)	
Parent gesture type		I SIB (42)	
Use of telegraphic speech	I ASD (55)		
<i>Social factors</i>			
Frequency of other-directed vocalizations		I ASD (104)	
Increased attention to eyes and face		I ASD (45), I SIB (37)	
Increased attention to mouth		I ASD (54), I NOT (91)	I ASD (45)_
Intentional communication		I ASD (87)	
Joint attention	3 ASD (359), I SIB (31), I NOT (50)	2 ASD (169), I SIB (50), 2 NOT (280)	
Larger latency to respond to to one another			I SIB (25)
Object imitation		2 ASD (126)	
Object play		I ASD (61)	
Percentage simultaneous speech between parent and child			I SIB (25)

(continued)

Table 2. Continued.

	Receptive language	Expressive language	General language abilities
Preference for speech over nonspeech		1 SIB (20)	
Preference for synchronous over asynchronous videos			1 SIB (45)
Relative preference for faces over objects		1 SIB (14)	
Social motivation		1 ASD (87)	
Social responsiveness	1 ASD (249)	1 ASD (249)	
Symbolic comprehension		1 ASD (249)	
Age-related and developmental factors			
<i>Early language abilities</i>			
Early child vocalizations		1 ASD (87)	
Incremental language processing	1 ASD (17)		
Initial child language abilities		2 ASD (177)	
<i>Cognitive factors</i>			
Nonverbal cognition	1 ASD (104), 1 SIB (31)	2 ASD (239), 1 SIB (31), 1 NOT (42)	
<i>Gestures</i>			
Child gesture quantity	1 SIB (40)		
Child gesture type		1 ASD (72)	
<i>Motor skills</i>			
Composite score motor skills	1 ASD (38), 1 SIB (31)	1 ASD (38), 1 SIB (31)	
Fine motor skills	1 SIB (499), 1 NOT (73)	2 SIB (572), 1 NOT (73)	
Gross motor skills	1 SIB (499)	1 SIB (499)	
Motor imitation ability		1 SIB (50)	
Postural control	1 SIB (8)	1 SIB (8)	
<i>Speech production</i>			
Speech production abilities		1 ASD (27)	
<i>Word learning</i>			
Ability to map differentially stressed labels to objects	1 SIB (19)		
Use of mutual exclusivity in word learning	1 ASD (32)		

Note: Numbers refer to the number of articles in which each factor was found to be significantly related to one or more language measures. The number is followed by the population that was examined in each article: ASD for autistic children and SIB for EL-siblings. The number between brackets is the number of autistic children or EL-siblings in total included in the data collection project (i.e., without control group). Thus, 2 ASD (100), 1 SIB (20) indicates that the corresponding factor was identified in two articles examining in total 100 autistic children and in one examining in total 20 EL-siblings. Articles drawing from the same study sample are only taken into account once. NOT indicates that one or more studies did not replicate the significant effect.

Disclaimer: SIB groups are not split between those who go on to receive a diagnosis and those who will not. If this information is available, it is provided in the written summary of the specified factor below.

*This effect was rendered insignificant after correcting for multiple comparisons.

The systematic literature review identified a total of 56 factors that were significantly associated with language abilities in autistic children and/or EL-siblings. Thirteen factors were only investigated in broad language abilities without differentiating between receptive or expressive language; 17 and 36 factors were identified for receptive language and expressive language, respectively. Some factors were associated with both receptive and expressive language abilities. Studies more frequently examined expressive language abilities compared to receptive abilities. Receptive language abilities were exclusively investigated with standardized tests. These instruments generally

included an expressive measure as well. Thus, when receptive language was investigated, expressive language was almost always also investigated with the same instrument. On the other hand, isolated expressive language abilities (e.g., mean length of utterance [MLU], expressive vocabulary etc.) were often examined using (semi-)spontaneous language samples, for example, acquired during parent-child interactions, where receptive language abilities were generally not additionally assessed. This leads to only one study uniquely investigating receptive language abilities (Mathée-Scott et al., 2021), while 13 studies uniquely considered expressive language abilities. An overview of the

56 factors and their association with receptive and expressive language abilities can be found in Table 2.

The large table including all study characteristics and main results can be found in Table 2 in the Appendix.

We grouped the established language-associated factors into three main categories: biological factors (subcategories: biological sex and brain-based factors); psychosocial and environmental factors (subcategories: autism traits, environmental factors, nonverbal cognition, parental input, social factors); and age-related and developmental factors (subcategories: early language abilities, gestures, motor skills, speech production abilities, word learning). Below, each of these categories will be discussed per sample (autistic children and EL-siblings).

Factors associated with language in autistic children

Biological factors

Brain-based factors. Two included research articles examined brain-based factors in children with an established diagnosis. Using structural MRI, Chen et al. (2021) investigated the role of the speech-evoked auditory brainstem response (speech-ABR) and broad language abilities in three- to six-year-old autistic children. The speech-ABR is a neurological test to evaluate the auditory brainstem function in response to auditory stimuli (Källstrand et al., 2014; Spitzer et al., 2015). The authors classified participants into subgroups based on their speech-ABR to complex sounds, which was either typical or atypical. Autistic children with an atypical speech-ABR had significantly lower language scores than those with a typical response. Moreover, for all autistic children, the surface area of the left rostral middle frontal gyrus, part of the dorsolateral prefrontal cortex, had an indirect effect on language via the wave V amplitude, a wave generated in the upper brainstem as a response to an auditory stimulus, which, as Chen et al. (2021) propose, suggests that subcortical dysfunction caused by cortical deficits may impair language ability in autistic children.

The second study utilized diffusion tensor imaging to examine a sample of three-year-old autistic male participants. It was established that fractional anisotropy, a measure of connectivity that evaluates white matter, in the occipital portions of the left and right inferior longitudinal fasciculus, a pathway between the occipital and temporal lobes, was positively linked to both expressive and receptive language (Naigles et al., 2017).

Other biological factors. The only other biological factor examined was biological sex. Two studies, with conflicting results, examined this in autistic children (Øien et al., 2018; Wallisch et al., 2021). One study (Wallisch et al., 2021) reported that parents indicate fewer language concerns for autistic females compared to autistic males

(respectively, 55.6% and 72.4%), while the other (Øien et al., 2018) found that autistic females were more likely to have greater language impairment compared to autistic males. Operationalization of language may play a part in the diverging results: one study examined only current expressive language levels (Øien et al., 2018), while the other investigated both present and past parent concerns about receptive and expressive word-level difficulties (Wallisch et al., 2021). Gender bias may also play a role as autistic females may express their autism traits differently and are known to mask their traits more (Hull et al., 2020; Schuck et al., 2019).

Psychosocial and environmental factors

Autism traits. Autism traits, specifically the severity of social communicative difficulties and restricted and repetitive behaviors, were investigated in autistic children in two included articles (Kim et al., 2020; Nevill et al., 2019). The severity of social communication impairments was negatively associated with receptive and expressive language in one study investigating six-year-old children (Kim et al., 2020), but not in a second study investigating preschoolers (Nevill et al., 2019). This second study also did not find significant effects of restricted and repetitive behaviors on the language abilities of autistic children (Nevill et al., 2019), which was not examined in the first study (Kim et al., 2020).

Environmental factors. Three environmental factors were identified: the presence of Broader Autism Phenotype (BAP) traits in mothers (Flippin & Watson, 2018), serum folate blood levels (Li et al., 2021), and socioeconomic status (Olson et al., 2021). Flippin and Watson (2018) examined the presence of BAP traits in parents using the Broad Autism Phenotype Questionnaire (self-report) (Flippin & Watson, 2018) in relation to the language abilities of autistic children. This questionnaire contained questions related to three subscales reflecting ASD characteristics: aloofness, rigidity, and difficulties with pragmatic language. Only mother rigidity was significantly correlated with child language abilities, even after controlling for verbal responsiveness. This result is likely indicative of a stronger history of interaction between children and their mothers compared to fathers, as almost all mothers participating in the study identified as the primary caregiver.

In the study of Li et al. (2021), serum folate levels were examined. Serum folate is derived from dietary sources and low levels of serum folate have been previously linked to developmental disorders (Desai et al., 2016). In this study, autistic children ($n = 1300$) exhibited lower serum folate levels compared to neurotypical children, potentially due to feeding problems (e.g., being a picky eater, reduced vegetable intake). Higher serum folate blood levels were associated with better general language abilities, but only in children three years and younger. The authors state that

associations of serum folate levels may differ per age, as clinical manifestations of autistic children differ over time too (Li et al., 2021). Causal relationships between serum folate and language abilities were not directly established and a confounding variable may be present. For example, both feeding problems and language difficulties are frequently present in autistic children (Baraskewich et al., 2021), with the first potentially leading to reduced serum folate levels. Serum folate levels may in turn be associated with language levels due to the co-occurrence of language difficulties and feeding problems. More research is needed to examine the relationship between food intake and language abilities in autistic children.

Lastly, Olson et al. (2021) examined the association between multiple factors pertaining to SES, specifically household income, maternal and paternal education level, and median neighborhood SES by postal code and expressive and receptive language. The results show that maternal education was significantly related to parent-reported and clinician-rated receptive language, and parent-reported expressive language abilities for the entire sample (autistic and neurotypical children), with lower maternal education indicating lower child language abilities. These results were however rendered insignificant after controlling for multiple comparisons.

Parental input. Three articles investigated the influence of parental input on the language abilities of autistic children (Bang & Nadig, 2015; Flippin & Watson, 2015; Venker et al., 2015). First, based on parent–child interactions, Flippin and Watson (2015) investigated mothers' and fathers' verbal responsiveness and the relationship with broad language abilities of autistic children. They demonstrated that only the frequency of fathers', but not mothers', verbal responsiveness, appeared to be associated with child language scores (Flippin & Watson, 2015).

Another indexation of parental input is the parent MLU. In their study, Bang and Nadig (2015) showed maternal MLU to be positively related to expressive language abilities of both autistic and neurotypical children.

Lastly, the role of parent telegraphic speech on autistic children's expressive language abilities was studied. Telegraphic speech describes an expressive language style focused on content words, often omitting adjectives, articles, and other grammatical morphemes. Although a natural stage in all children's language development, it is sometimes adopted by parents of autistic children as some clinicians recommend this technique for language learning in these children (Kleeck et al., 2010). Venker et al. (2015) explored parent use of telegraphic speech during parent–child interactions and expressive language levels. They demonstrated that parent use of telegraphic speech at three years negatively correlated with the number of different words used by autistic children one year later, even after controlling for initial language levels and nonverbal cognitive ability. Telegraphic language input may discourage

imitation of grammatical utterances, hence potentially preventing children from learning new words through syntactic bootstrapping (Venker et al., 2015).

For all of these parent–child language relationships, it is important to mention that they may be more reciprocal than causal and one-directed (Dale et al., 2015). For example, talkative children may elicit more or different language input from their parents than children that talk less, thus making children contribute to their own language development through their parents (Davis & Hathaway, 1982; Lopez et al., 2020; Sameroff, 2010).

Social factors. Social factors were among the most frequently identified variables in the included articles and were mostly related to expressive language rather than receptive language. One important variable investigated in the context of social factors was joint attention, although mixed results were observed. One longitudinal study found significant, positive associations between joint attention and expressive language growth and baseline receptive language in autistic children (Frost et al., 2022), while two other studies found significant effects for autistic children's receptive language only, although language growth was not taken into account (Nevill et al., 2019; Taylor et al., 2020).

Furthermore, two eye-tracking studies examined attention to the face during videos of a person talking in an autistic sample. It was shown that attention to the eyes and mouth over other facial features was related to better language scores in both autistic and neurotypical children (Righi et al., 2018). In the same study, differential sensitivity to speech processing was examined by showing autistic and neurotypical children videos of a woman speaking, either with synchronous or asynchronous audio (Righi et al., 2018). The authors showed evidence that attention to synchronous over asynchronous videos was correlated with better language abilities for both autistic and neurotypical children (Righi et al., 2018).

Another study found that looking at the mouth over looking at the eyes was significantly and positively related to expressive language in 20-month-old autistic children who had already acquired first words, but not for autistic children who had not yet acquired speech at the same age, or neurotypical children (Habayeb et al., 2020).

To the best of our knowledge, no studies have yet been conducted to examine potential cascading relationships between attention to facial features, parent language input, and child language. It may be the case that parents of children that pay a lot of attention to their caregiver's mouth and eyes are more inclined to communicate and interact with their child than parents of children who do not frequently look at their mouth and/or eyes. This increased social interaction would in turn provide the child with additional language input that positively influences the child's language.

Other factors examined in autistic children were frequency of other-directed vocalizations (Nevill et al.,

2019), object imitation skills (Frost et al., 2022; Şengül et al., 2021), object play (Şengül et al., 2021), parent-rated social motivation (Su et al., 2021), and social responsiveness and symbolic comprehension (Taylor et al., 2020). Nevill et al. (2019) showed a positive association between the frequency of other-directed vocalizations and expressive language abilities of autistic children. Frost et al. (2022) and Şengül et al. (2021) also observed a significant positive relationship between expressive language and object imitation skills. However, this effect disappeared when joint attention was added to the model, suggesting that object imitation does not provide unique variance in the prediction of expressive language abilities (Frost et al., 2022). Object play (play complexity with different toy sets) was related to expressive language too, as children who received better scores for object play (and thus showed more complexity), were less likely to be minimally verbal (Şengül et al., 2021).

Social motivation (i.e., the motivation to engage in social communication) was also related to expressive language, but this effect was mediated by intentional communication, indicating that autistic children with stronger social motivation were more likely to frequently produce instances of intentional communication, in turn leading to better expressive language abilities (Su et al., 2021). Symbolic comprehension, a term referring to the ability to understand social communication, such as gesture use, was related to the expressive language abilities of autistic children, with poor symbolic comprehension indicating lower expressive language levels (Taylor et al., 2020). Social responsiveness (i.e., the response of the child to the emotional expression of the clinician) was related to both expressive and receptive language in autistic children (Taylor et al., 2020).

Age related and developmental factors

Early language abilities. Initial child language abilities were strongly and positively correlated with later expressive language abilities (Song & So, 2022; Torras-Mañá et al., 2016), indicating some consistency over time: those who do well on early measures of language are more likely to do well later on too. Frequency of early child vocalizations (McDaniel et al., 2020) (independent of communicative intent, for other-directed vocalizations see Social factors) was also positively associated with later expressive language abilities in autistic children. Being able to incrementally process language was associated with receptive language in autistic preschoolers (Venker et al., 2019). Incremental language processing means using semantic contexts as a listener to facilitate prediction of what the speaker will say next (e.g., after the verb “read” it is more likely to hear the noun “book” than the noun “juice.” Using an eye-tracking task, the authors show that an increase in accuracy at looking at the correct target after hearing an oral stimulus was associated with stronger

receptive language skills. The direction of this association is however not clear-cut: it is also possible that better receptive language skills facilitate incremental language processing (Venker et al., 2019).

Nonverbal cognition. An often-investigated developmental predictor for language abilities was nonverbal cognitive abilities (Nevill et al., 2019; Song & So, 2022; Torras-Mañá et al., 2016). Torras-Mañá et al. looked at the association between nonverbal cognitive abilities and expressive language abilities in four-year-old Spanish and Catalan speaking autistic children. They revealed a significant association between nonverbal cognitive abilities and later oral language, with 72% of the children with poor early nonverbal cognitive abilities remaining minimally verbal and 82% of the children with typical early nonverbal cognitive abilities attaining phrase level to fully fluent verbal language at the age of four years old. Nevill et al. (2019) replicated this positive association, but stated that even (some) autistic children with typical nonverbal cognitive abilities were still at risk of developing language impairments (Nevill et al., 2019), indicating that low nonverbal cognition cannot be the only explanation for the language impairments.

One study did not establish a significant association between nonverbal cognition and language in autistic children (Song & So, 2022). This discrepancy may be due to differences in sample age. Participants in this study were, on average, over a year older at the time point of language evaluation compared to participants in the other studies. It may also have to do with differing language assessments, with this last study (Song & So, 2022) utilizing a spontaneous speech sample to characterize expressive language and the other studies employing standardized language tests (Nevill et al., 2019; Torras-Mañá et al., 2016). Previous research has indicated that autistic children show significantly more impairments on spontaneous language measures compared to standardized tests, but these results should be interpreted with caution due to the lack of psychometric norms for spontaneous language approaches (Condouris et al., 2003).

Gestures. Gesture type was shown to be associated with language abilities (Okcun-Akcamus et al., 2019). Especially declarative gestures (gestures to direct a person’s attention to something the child finds interesting) and conventional gestures (gestures that are symbolic, such as waving hello), but not imperative deictic gestures (pointing to direct another person’s attention to obtain a goal) were significantly correlated with expressive language in both autistic and neurotypical children (Okcun-Akcamus et al., 2019).

Motor skills. Only one included study examined motor abilities in relationship with language in autistic children and found that a composite score of motor abilities was significantly related to receptive and expressive language, with lower motor skills being related to lower language scores and vice versa (Wu et al., 2021).

Speech production. Saul and Norbury (2020) investigated diverse aspects of minimally verbal children's phonetic repertoire and their impact on expressive language. Their results show that speech production abilities at an average age of four years were significantly associated with expressive language one year later. The authors suggest the presence of a potential additional speech-sound production deficit in minimally verbal autistic children that contributes to the deficits in expressive language. While some work in older children has shown that speech production abilities do seem to influence expressive language (Chenau et al., 2019), more research in younger children is needed to uncover the role of motor speech impairments in language development in autism.

Word learning. Mathée-Scott et al. (2021) investigated the use of "mutual exclusivity" in an eye-tracking task and its relation to receptive language abilities. Mutual exclusivity is a strategy for word learning in which the child maps a novel label to a novel object and not to an object they already have a label for (Markman & Wachtel, 1988). The authors show that autistic children who appear to struggle with the mutual exclusivity strategy, have significantly lower receptive language abilities than those that do correctly apply this strategy (Mathée-Scott et al., 2021).

Factors associated with language in EL-siblings

While reading the paragraphs below, please be aware that EL-sibling populations are highly heterogeneous. Not all siblings of autistic children will go on to receive an autism diagnosis themselves (e.g., Hansen et al., 2019), some will go on to follow a typical developmental path or develop subclinical characteristics that can fall under the BAP (e.g., Georgiades et al., 2013). We have included papers that examined factors associated with language in siblings who later go on to receive an individual diagnosis below and not in the category of autistic individuals. This is because those factors were examined at a time when a diagnosis could not yet reliably be made and to gain a better overview of a potential developmental timeline. Moreover, for some of the described samples, it is not clear if some of the participants go on to receive an individual diagnosis, making it not possible to reliably distinguish between siblings with and without later diagnosis.

Biological factors

Brain-based factors. Brain-based factors were frequently investigated in samples involving EL-siblings, as many of the included papers here draw from the same overarching research study (the Infant Sibling Project) (e.g., Romeo et al., 2021; Wilkinson et al., 2019). Multiple articles, many drawing from the same longitudinal study sample, examined frontal EEG power in different frequency bands during a

resting-state task. The intercepts of frontal delta, gamma, and theta power at six months old were significantly associated with broad language abilities at 24 months, both in EL-siblings who would go on to receive a diagnosis and those who would not (Wilkinson et al., 2020; Wilkinson et al., 2019). Interestingly, the direction of the effect of frontal gamma power was reversed for EL-siblings who received a diagnosis and those who did not: whereas for this first group high gamma power at the age of six months was associated with lower language scores, for EL-siblings without eventual diagnosis, it was related to increased language ability (Wilkinson et al., 2019).

When distinguishing between receptive and expressive language, increased frontal gamma power was established to be negatively related to expressive language for EL-siblings regardless of later diagnostic status, but not for those at typical likelihood (Wilkinson et al., 2019). This effect was however largely driven by females, underscoring the importance of including biological sex in analyses (Wilkinson et al., 2019). Frontal high alpha power was also positively associated with expressive language for EL-siblings with and without a later diagnosis and siblings of neurotypical children (Levin et al., 2017), as was left frontal-central alpha coherence, a measure of connectivity (Tran et al., 2021, not part of the Infant Sibling Project).

Gamma power was investigated as a mediator in the relation between parental language input and child language abilities (Romeo et al., 2021). Parent-child interaction was used to characterize the quality and quantity of parental input when children were 18 months old and relationships with expressive and receptive language at 24-months old were investigated. An association was found with expressive language for the whole sample (siblings of autistic and neurotypical children), but only for EL-siblings who would ultimately go on to receive a diagnosis, the effect was mediated by frontal and temporal gamma power (Romeo et al., 2021). Moreover, replicating previous results of Wilkinson et al. (2019), gamma power had been directly negatively correlated with expressive language scores in for the whole sample, but especially for EL-siblings who received a later diagnosis (Romeo et al., 2021).

Glauser et al. (2022), also drawing from the sample of this larger research study, investigated the neural correlates of face processing and their impact on receptive and expressive language. Using event-related potentials (ERPs), they showed that an increased P400, an ERP sensitive to face processing, response to a picture of the EL-siblings' mother over a picture of a stranger was positively associated with receptive and expressive language abilities of EL-siblings that would later receive a diagnosis, but not for EL-siblings without later diagnosis or siblings of neurotypical children (Glauser et al., 2022).

In two other EEG studies investigating EL-siblings, an auditory oddball task was used (Kolesnik et al., 2019;

Riva et al., 2018). With this paradigm, children heard a sequence of “standard” stimuli, in which a different stimulus was occasionally and seemingly randomly introduced. Studying ERPs related to auditory processing, one study showed that P3 peak latency, an ERP assumed to be a measure of time needed to evaluate and categorize a stimulus (Duncan-Johnson, 1981), was significantly delayed in EL-siblings and in children with an elevated likelihood of developmental language disorder, and this longer latency was negatively associated with expressive vocabulary in the whole sample (Riva et al., 2018). The second study investigated cortical reactivity and demonstrated that for all children in the sample (EL-siblings and neurotypical children), higher cortical reactivity at nine months was associated with reduced receptive language growth between 8 and 36 months. No significant effects were observed for expressive language (Kolesnik et al., 2019).

Lastly, a functional MRI study investigating neural sensitivity to speech prosody indicated that for EL-siblings, a greater signal increase during speech stream exposure in the Heschl’s gyrus was associated with better expressive language scores at 36 months (Liu et al., 2020). The Heschl’s gyrus contains the primary auditory cortex and the superior temporal gyrus, which includes Wernicke’s area and is involved in auditory processing. Interestingly, an fNIRS study examining neural correlates of speech processing did not observe a correlation with language abilities in EL-siblings, although there was a positive effect on language in neurotypical children (Pecukonis et al., 2021).

Other biological factors. Other biological factors were not examined in samples of EL-siblings.

Psychosocial and environmental factors

Autism traits. In EL-siblings, the severity of social communication impairments, restricted and repetitive behaviors and hypo-reactivity to sensory stimuli were examined in two separate studies. The first study found that the severity of social communication impairments and restricted and repetitive behaviors were negatively associated with receptive language growth, but not expressive language growth between 10 and 36 months (Bruyneel et al., 2019a). Five out of 31 EL-siblings in this study would later receive a diagnosis and 11 were found to present with the BAP.

In the second study, it was established that hyporeactivity to sensory stimuli at 14 months was negatively related to language abilities at 23 months in EL-siblings (Grzadzinski et al., 2021). This effect was however mediated by parental verbal responsiveness, meaning that increased parental responsiveness may attenuate negative effects on language associated with hyporeactivity to sensory stimuli (Grzadzinski et al., 2021). In this study, 34% of the EL-siblings who were available for a preschool follow-up received a diagnosis.

Environmental factors. Environmental factors identified in the included articles were only examined in samples of autistic children and not in EL-siblings.

Parental input. Several articles examined parental input in EL-siblings. The first article showed that for EL-siblings, similar to autistic children, parent verbal responsiveness at 14 months was directly related to broad language abilities at 23 months (Grzadzinski et al., 2021); 34% of the EL-siblings who were available for a follow-up ultimately received a diagnosis.

Secondly, apart from parental verbal responsiveness, significant positive effects for parental (mostly maternal) MLU at 12 and 18 months on general language abilities (Choi et al., 2020a) and expressive and receptive language specifically (Romeo et al., 2021) have been observed for EL-siblings one year later, even after controlling for parental education, family income, and initial child language levels (Choi et al., 2020a; Romeo et al., 2021). These results hold for both EL-siblings who went on to receive a diagnosis and for those who did not, but no significant effects were found for siblings of neurotypical children (Choi et al., 2020a; Romeo et al., 2021).

Lastly, parent (mostly maternal) gesture frequency was related to later expressive language abilities of their children, both for EL-siblings with and without later diagnosis and siblings of neurotypical children (Choi et al., 2021b). The type of gestures parents used was important too, as specifically declarative gestures and conventional gestures, but not imperative gestures were associated with expressive language across the sample (Choi et al., 2021a). Furthermore, maternal gesture use was related to broad language abilities in EL-siblings without a later diagnosis and siblings of neurotypical children, but not in EL-siblings who went on to receive a diagnosis at the end of the longitudinal study (Talbot et al., 2013).

Social factors. As for autistic children, joint attention was a frequently examined social factor for EL-siblings, although resulting in mixed findings. One study found a significant association between joint attention and receptive language but not expressive language (Bruyneel et al., 2019b), while another study showed the reversed pattern and found associations with expressive language only (Edmunds et al., 2017), regardless of later diagnostic status.

Other social factors were also important for expressive language. One eye-tracking study examining social factors showed that a relative preference for faces over objects was related to higher expressive language scores in EL-siblings, but not in siblings of neurotypical children (Droucker et al., 2013). Another eye-tracking study revealed that, similar to autistic children, increased attention to the eyes and face over looking at the mouth in six-month-old EL-siblings, independent of later diagnostic status, was negatively related to expressive, but not receptive language at eighteen months old (Wagner et al., 2018). Eight of the 37 EL-siblings participating in this

study would go on to obtain a formal diagnosis. Interestingly, another eye-tracking study found no significant effects of preferential attention to specific facial features on expressive nor receptive language for EL-siblings without later diagnosis (Chawarska et al., 2022). Another factor positively associated with expressive language abilities in EL-siblings was a preference for speech over non-speech stimuli (Yamashiro et al., 2020).

Three factors were only explored for broad language abilities rather than differentiating between receptive and expressive language: the percentage of simultaneous speech between parent and child, a larger latency to respond to one another during parent–child interactions and a preference for synchronous videos over asynchronous speech videos (Northrup & Iverson, 2015). The amount of simultaneous speech between parent and child (i.e., the amount that both spoke at the same time) was indicative of later language delay, and a larger average latency to respond to one another occurred significantly more often in EL-siblings with comorbid language delay (Northrup & Iverson, 2015). The study did not differentiate between the later diagnostic status of EL-siblings. Note that the effects of joint attention for EL-siblings were already discussed above, in the paragraph concerning autistic children.

Age related and developmental factors

Early language abilities. Early language abilities were solely examined in samples of autistic children.

Nonverbal cognition. Similar to the results in autistic children, for EL-siblings too, a significant positive association with both expressive and receptive language was confirmed (Bruyneel et al., 2019a). In this study, five out of 31 EL-siblings received an eventual diagnosis and 11 were found to present with the BAP.

Gestures. Both gesture frequency and gesture type were important for language abilities in EL-siblings. First, the frequency of gestures were significantly associated with receptive, but not expressive language scores at 24 months in siblings with and without elevated likelihood, regardless of later diagnostic status (Choi et al., 2020b).

Motor skills. Similar to for autistic children, composite scores of motor abilities were significantly associated with language abilities of EL-siblings. However, these results were partially mediated by joint attention, as motor skills impacted the ability to execute joint attention behaviors (e.g., object sharing), and joint attention in turn affected language abilities (Bruyneel et al., 2019b). Of this sample of 32 EL-siblings, six ultimately received a diagnosis and 11 presented with BAP.

When investigating motor skills in EL-siblings further, one longitudinal study showed that fine motor skills specifically were significantly and positively linked to expressive language abilities in the whole sample (Choi et al., 2018). Siblings who went on to receive a diagnosis obtained significantly lower fine motor scores compared to siblings

who would not (Choi et al., 2018). These results were replicated by Patterson et al. (2022) who found that early fine and gross motor trajectories from 6 to 24 months were correlated with receptive and expressive language abilities at 36 months old in EL-siblings with and without eventual diagnosis. Their results show that flatter developmental trajectories of motor abilities were related to lower language scores, whereas accelerating trajectories were associated with higher language scores (Patterson et al., 2022).

Edmunds et al. (2017) investigated motor imitation abilities and later parent-reported expressive language abilities in EL-siblings. Significant effects were observed indicating that better motor imitation abilities were related to better expressive language outcomes for EL-siblings and siblings of neurotypical children. Similar to Bruyneel et al. (2019b), the effect was mediated by response to joint attention (Edmunds et al., 2017). The diagnostic status of the children in this study was unknown as participants were still too young for reliable assessment at the end of the study.

In contrast to the above results, one study examining fine motor skills and its relationship to expressive and receptive language in EL-siblings indicated that although fine motor and language pathways correlated highly over time, the two skills were not coupled, as differences in children's baseline fine motor abilities did not affect the growth rate of language abilities (receptive and expressive) (Deserno et al., 2022). This was the case for both EL-siblings who would later receive a diagnosis as well as for those who would not (Deserno et al., 2022).

Lastly, the role of postural control at six months of age and later expressive and receptive language at 12 months was explored in a sample of eight EL-siblings (Kyvelidou et al., 2021). The results indicate that EL-siblings who had faster control over their posture, had significantly higher receptive language scores, and that “steady sitters” (i.e., children with low random movement) had better receptive and expressive language outcomes. EL-siblings included were still too young for formal assessment of their diagnostic outcome.

Speech production. Speech production abilities were only examined in autistic children.

Word learning. One factor did not fit the defined categories, namely, the ability to map differentially stressed labels to objects (FERENCE & CURTIN, 2015), which was shown to play a role in the language abilities of EL-siblings. Mapping differentially stressed labels to objects entails the ability to use linguistic cues such as prosody and stress to match unfamiliar words to objects, thus facilitating word learning. In a longitudinal study exploring this ability in EL-siblings, success on an experimental task at 12 months old, indicating the successful mapping of labels to objects, predicted better expressive language abilities one year later. This was however not the case for siblings of neurotypical children. For these children, success on the task was only related to current language comprehension

(Ference & Curtin, 2015). An overview of all discussed factors split by group is shown in Table 2.

Risk of bias and quality assessment

Risk of bias of eligible articles was assessed with the Newcastle–Ottawa Scale (NOS) for case–control studies (Wells et al., 2019). The NOS employs a star rating system assessing three broad categories: selection of study groups and, for studies including a control group, comparability of groups and ascertainment of the outcome. Between zero and nine stars can be awarded to each article, the more stars a study receives, the lower the risk of bias. The first and second authors independently assessed the risk of bias of all included studies. Any discrepancies in ratings were resolved among the reviewers by discussion. The risk of bias varies from low to high risk and is summarized in the appendix in Table 2.

Discussion

We identified 56 factors from recent literature that were significantly associated with receptive and/or expressive language abilities in autistic children and EL-siblings (see for an overview Table 2) and summarized them into three broader categories (biological factors; psychosocial and environmental factors; age related and developmental factors). We found that, on average, autistic children and EL-siblings obtained significantly lower receptive and expressive language scores than their neurotypical peers. These results are in line with a rich body of evidence showing that expressive and receptive language deficits are highly prevalent in autistic children and EL-siblings (Kwok et al., 2015; Pickles et al., 2014; Talbott et al., 2015; Wittke et al., 2017).

Multiple factors associated with language abilities in autism

Our results make apparent that no single factor alone can explain the heterogeneity in language abilities of autistic children and EL-siblings. Although our findings are scattered, as most implicated factors were only investigated in a single study, we did identify some similarities across studies. Especially joint attention was frequently shown to be associated with receptive language (Bruyneel et al., 2019b; Frost et al., 2022; Nevill et al., 2019; Taylor et al., 2020) and expressive language (Edmunds et al., 2017; Frost et al., 2022), with the presence of joint attention behaviors being linked to better language skills. This is in line with previous work indicating that joint attention abilities are important for emerging language, and delays or absence of these behaviors is related to lower language abilities and language delays (Charman et al., 2003; Murray et al., 2008). A recent literature review of joint attention

skills in autism however showed that while joint attention skills are indeed important for language acquisition in autism, there are autistic children with very few joint attention behaviors that still successfully develop advanced language abilities (Kissine et al., 2023). This result further underscores the notion that no one factor determines language development in autism but an interplay between joint attention and other factors appears to be in place.

Apart from joint attention, other social factors, especially relative attention to specific facial features of others, were primarily implicated in expressive language (Habayeb et al., 2020; Righi et al., 2018; Wagner et al., 2018). These findings confirm prior work establishing evidence that social factors predict expressive language abilities in autistic children and EL-siblings (e.g., Luyster et al., 2008; Pickard & Ingersoll, 2015; Yoder et al., 2014). However, the fact that we found more factors associated with expressive than receptive language can in part be attributed to a higher number of studies focusing on expressive language.

Child characteristics such as nonverbal cognition and initial child language abilities were recurrently positively associated with both receptive and expressive language abilities (Bruyneel et al., 2019a; Nevill et al., 2019; Song & So, 2022; Torras-Mañá et al., 2016). Children with typical or above typical nonverbal cognition were less likely to have language deficits (Nevill et al., 2019; Torras-Mañá et al., 2016). (Above) average nonverbal cognition may thus serve as a protective factor for language deficits in autistic children and EL-siblings. Hence, (early) verbal language, cognition, and social impairments are important factors to take into account when delineating a child's potential risk for language deficits in autism, especially for expressive language deficits.

Other behavioral components in this context are autism traits and motor abilities. Autism traits are likely to play a role in language, as mainly impairments in the social communication were negatively related to expressive and receptive language (Bruyneel et al., 2019a; Kim et al., 2020). Well-developed early motor abilities in autistic children and EL-siblings were also shown to be related to better later language abilities (Bruyneel et al., 2019b; Choi et al., 2018; Edmunds et al., 2017; Kyvelidou et al., 2021; Wu et al., 2021). It remains unclear however if there is a direct effect of motor skills on language, or if this relationship is mediated by other variables, such as joint attention.

Lastly, exploring a neurocognitive component, different brain-based elements appeared to be of importance. Especially frontal EEG power in alpha, delta, gamma, and theta bands during the first year of life was frequently investigated and partly correlated with later expressive language abilities in EL-siblings (Levin et al., 2017; Romeo et al., 2021; Wilkinson et al., 2020; Wilkinson et al., 2019). It should however be taken into account that most included investigations were part of a larger overarching research study and thus examined the same sample.

While we have identified many different overarching factors associated with language abilities in autism, the role of genetics remains underexposed. Throughout the literature search, we did not encounter studies compliant with our inclusion criteria that investigated the role of genetics on language abilities in young autistic children or EL-siblings. As autism itself has a large genetic component (e.g., Chaste & Leboyer, 2012; Geschwind, 2011; Rylaarsdam & Guemez-Gamboa, 2019), investigating genes in the context of language abilities in autistic children and EL-siblings seems a compelling avenue for future research.

Research on EL-siblings versus autistic children

Many of the identified associated factors were either only examined in autistic children or in EL-siblings. Only six factors were researched and found to be significantly associated with language, in both groups (the severity of social communication impairments, nonverbal cognitive abilities, motor abilities, maternal MLU, attention to facial features, and joint attention). To help determine shared and distinct underlying risk factors for language deficits in autistic children and siblings, research should aim to examine the same factors in both autistic and EL-siblings. Knowing if certain risk factors are shared between autistic children and EL-siblings or if unique features exist can for example help determine if it is necessary to develop separate targeted language intervention strategies for autistic children and EL-siblings or if such strategies can be shared.

Differences and similarities between children with and without autism

There appears to be substantial overlap in the factors implicated in language abilities between autistic children and EL-siblings on one hand and neurotypical children on the other (e.g., Bang & Nadig, 2015; Okcun-Akcamus et al., 2019). For example, parents' language input and parents' gesture use were both positively related to expressive language abilities in autistic and neurotypical children (Bang & Nadig, 2015; Okcun-Akcamus et al., 2019), and early cortical reactivity in response to repeated tones was associated with reduced language growth for both EL-siblings and siblings of neurotypical children. This overlap shows that while several aspects underlying language development in autism may differ from neurotypical development, there are also some aspects that appear shared between them, indicating similarities in developmental influences involved in language acquisition between neurotypical and neurodiverse populations. To gain a clearer idea of shared and distinct mechanisms, it is important for future research to include a neurotypical control group in their experimental design.

Where differences were observed, they could often be at least partially explained by factors inherent to autism. For

example, the frequency of restricted and repetitive behaviors was negatively associated with receptive language in EL-siblings, but not in siblings of neurotypical children (Bruyneel et al., 2019a). The frequencies of these behaviors were significantly higher in EL-siblings, as they make up a crucial part of autism. This increased frequency may have a relative negative effect on language abilities, but absence of restricted and repetitive behaviors may not be of importance for language abilities. Unfortunately, many studies did not have large enough samples to investigate autistic and neurotypical groups separately. This is even more so the case for distinguishing groups of EL-siblings with and without eventual diagnosis. Moreover, many studies did not provide enough information to characterize their autistic sample while autism is by definition a highly heterogeneous disorder. While some autistic individuals may be able to perform daily tasks on their own and have relatively low support needs, others have high support needs and need more help in certain aspects of everyday life. A high quantity of autism traits in an autistic individual may play a role in research outcomes as we have shown that autism traits are significantly associated with language outcomes in EL-siblings and autistic children. Thus, more research in larger samples, and consequently more power, is necessary and studies need to provide information that characterizes the sample of autistic individuals in their study.

Mixed findings and language assessment

Mixed results were frequently present in the literature (e.g., for biological sex [Øien et al., 2018; Wallisch et al., 2021] and speech processing [Liu et al., 2020; Pecukonis et al., 2021]). Part of these mixed, sometimes contradictory, findings may lie in the fact that studies used vastly different measures to assess language abilities which is likely to have effect on the language scores (e.g., Condouris et al., 2003; Kasari et al., 2013; Luyster et al., 2008; Thomas et al., 2022). Many autistic children have difficulties with generalizing across contexts, and their language use may differ between different contexts (e.g., everyday language with a parent vs. a formal assessment with a professional) (Nordahl-Hansen et al., 2014). This can result in different outcomes on different measures of language, thus showing the need for multiple measurements, even apart from difficulties in language assessments due to a short attention span, problems with cooperation, and lack of motivation (Akshoomoff, 2006; Feldman et al., 2005; Kasari et al., 2013).

Moreover, parents appear to underestimate their child's expressive language level and overestimate their child's receptive language in comparison to other assessments (Luyster et al., 2008; Miller et al., 2017; Venker et al., 2016). A better understanding of how different language measures relate to each may help provide clarity into some of the mixed results in the literature, for example, regarding the effect of biological sex. Lastly, research comparing different assessments is limited, thus it remains unclear if different assessments provide similar information or if they add

unique value (Nevill et al., 2019). Some studies included in this review employed a (semi-)spontaneous language sample, which, though time consuming to analyze, provides a more naturalistic and informative impression of the child's expressive language abilities and seems feasible to assess in a large part of children on the autism spectrum. However, standardized approaches with well-established norms for different age groups and different languages are currently lacking for spontaneous speech samples, making it difficult to establish cutoffs for language impairments.

Furthermore, receptive language abilities are difficult to capture in autistic children (McDuffie et al., 2005; Muller et al., 2022), especially those with limited spoken language (Muller et al., 2022). Standardized testing or parent report may not always fully capture autistic children's receptive language abilities and therefore, alternative, more implicit methods such as eye-tracking may be able to fill this gap (Plesa Skwerer et al., 2016; Venker et al., 2016).

Overall, our findings underscore the need for more uniform language assessment and more research into the different methodologies used to capture language in autism to ultimately make cross-study comparisons possible.

Limitations of the current review

Certain limitations of the current review should be considered. First, this review focuses on factors that are *associated* with language, which means there is not necessarily a direct causal relationship between all factors described here and language abilities in autistic children. We aimed to provide an overview of the different factors that have been associated with language in the past decade to gain a better understanding of what may underlie language differences in autism, but it is very difficult to examine true causality in observational studies. For this reason, it is important to stress that the results here cannot be interpreted as directly influencing language abilities in autistic children and confounding variables may be present. In line with this, we only included published articles that treated language abilities as the "dependent variable," even though the statistical analysis did not necessarily need to reflect one-directionality. This means that we might have missed many studies that show associations between language and another variable if they were for example described with language as the "predictor variable."

Second, this work focuses exclusively on children with a diagnosis of autism spectrum disorder as characterized by *DSM-5* criteria (American Psychiatric Association, 2013) and EL-sibs. This inevitably led to the exclusion of many meaningful research articles and, considering the overlap between previous and current diagnostic criteria, we have therefore likely missed important results. For example, Lombardo and colleagues authored several papers regarding MRI-data and language outcomes in autistic children (e.g., Lombardo et al., 2021; Lombardo et al., 2015; Lombardo et al., 2018), that unfortunately fell beyond the

scope of the current literature review as the children in their sample were diagnosed based on the *DSM-IV-TR* (American Psychiatric Association, 2000), which served as an exclusionary criterion here.

A third limitation of this review is that the average age of participants in included records could not exceed 6 years and 11 months. This age limit was chosen as language milestones are typically achieved by age six, and as previous research has shown that after this age variability in language skill becomes surprisingly uniform (Pickles et al., 2014). Taking advantage of the high variability in language abilities in autism during the years before, this age range is an ideal window to evaluate the early language development of autistic and neurotypical samples and the factors impacting this early heterogeneity. Moreover, including a larger age range would make it difficult to compare results across different age ranges as language skills likely rely on different underlying mechanisms that change over time and these developmental differences may obscure results (Tager-Flusberg, 2016). However, to gain a full overview of language development and a potential developmental shift in factors implicated in language abilities over time, older age groups until adolescence should be given attention in future investigations. Additionally, this review deliberately focuses on broad abilities in expressive or receptive language, but more fine-grained language processes, such as syntactic comprehension (e.g., quantifier processing) may ultimately shed more light on underlying cognitive processes of language that may or may not differ between those with and without autism. Such processes can often only be studied in older children given their age of acquisition.

Lastly, more general limitations that are frequently present in autism research should be acknowledged. Autistic children included in the samples discussed here likely only represent part of the autism spectrum, as some children would be unable to participate in the testing sessions of included studies. Especially those with high support needs may not be able to participate in research settings and are therefore often not included. This may in turn result in cascading high language scores in current research samples that do not reflect the entirety of the autism spectrum. Moreover, women are often not well represented in autism studies because there is a 4:1 male-to-female prevalence ratio indicating a male bias in autism prevalence (e.g., Baio et al., 2018). However, in recent years, cascading evidence has shown that this prevalence may not accurately reflect reality as women more often mask their autistic traits and may therefore be underdiagnosed (e.g., Hull et al., 2020; Schuck et al., 2019). Future research should therefore include more autistic women to better understand how biological sex and/or gender may influence language development in autism.

Additionally, generalizability of our results should be interpreted with caution as most studies included relatively small samples representing predominantly white, monolingual English-speaking children from middle to high socioeconomic backgrounds.

Conclusion

We identified several factors that were associated with receptive and expressive language abilities in autistic children and EL-siblings, such as joint attention, nonverbal cognition, early child language abilities, social factors, and motor abilities. More research is however necessary, as several potentially influential factors for language, such as a genetic one, are largely unexplored in young children. Moreover, many factors are as of now only examined in either EL-siblings or autistic children, making it difficult to determine whether factors associated with language abilities in one group, also accurately represent the other. Further investigating factors associated with language abilities should be considered in the context of risk factors and protective factors for language impairments in autistic children and EL-siblings as this may contribute to the development of early language intervention methods that can help prevent these impairments.

Availability of the data and material

The detailed coding manual can be requested from the first author.

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Supplemental material

Supplemental material for this article is available online.

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