# Studies assessing domains pertaining to structural language in autism vary in reporting practices and approaches to assessment: A systematic review

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**Lay Abstract**

Under the DSM-5, language impairment can co-occur with autism. It is not yet clear how research defines, reports, and characterizes structural language abilities of autistic individuals eligible for school-based special education services (ages 3 to 21 years) in the U.S. In the U.S., students typically must be formally diagnosed to be eligible for services and supports. However, the quality of diagnosis is only as good as the research evidence on which diagnosis depends. To evaluate evidence quality, we examined how studies of school-age autistic individuals report assessments of language ability. This systematic review included 57 studies using English language age-referenced assessments used to measure structural language. Findings showed many differences across studies in how language abilities were measured and reported. Also, none of the studies fully reported the variables relevant to characterizing language impairment. Outcomes were similar across versions of the DSM. Findings indicate that researchers and clinicians should pay attention to reporting diagnostic and grouping criteria. Carefully interpreting research evidence is critical for ensuring that diagnostic criteria and supports are representative of and accessible to autistic individuals and relevant parties.

**Abstract**

**Purpose:** Language in autism is heterogeneous, with a significant proportion of individuals having structural language difficulties and inclusion of language impairment (LI) as a specifier under DSM-5 criteria for autism. This systematic review asked: What are the reporting patterns of variables pertaining to structural language in autism prior to and after publication of the DSM5? What norm-referenced assessments does research use to characterize the language abilities of autistic individuals with respect to LI?

**Method:** This preregistered review (PROSPERO: CRD42021260394) followed PRISMA guidelines. Searches took place in September 2022 and included Linguistics and Language Behavior Abstracts, PsycINFO, PubMed, and the Directory of Open Access Journals. Search terms included three essential concepts: autism, language, and age. Two coders independently screened and evaluated articles.

**Results:** Searches yielded 57 qualifying studies, with mostly consistent reporting practices prior to and after the DSM-5. Studies varied in how they defined language groups and in what normreferenced measures they used.

**Discussion:** Interpreting research on structural language in autism requires attention to diagnostic and grouping criteria. Although inconsistency in reporting in original studies limited this review, better understanding the available information on structural language in autistic individuals ages 3 to 21 years may support identification of language needs.

**Studies assessing domains pertaining to structural language in autism vary in reporting practices and approaches to assessment: A systematic review**

Despite the fact that language in autism spectrum disorder (ASD) is heterogeneous (Magiati et al., 2014) and language impairment (LI) is common in autism (Boucher, 2012; Kwok et al., 2015), limitations in knowledge about the structural language abilities of autistic individuals across the spectrum limit the ability to provide supports (Interagency Autism Coordinating Committee, 2020). LI refers to difficulties with structural language, such as morphology, syntax, and grammar (Schaeffer et al., 2023). LI in autistic and nonautistic individuals is tied to negative educational, health, occupational, and social outcomes (Johnson et al., 2010; Magiati et al., 2014). Thus, addressing structural language in autism is important to improving the quality of the evidence base informing assessment and service delivery (Russell et al., 2019; Tager-Flusberg & Kasari, 2013).

First, the inclusion of LI in the diagnostic criteria for autism has changed over time (American Psychiatric Association [APA], 1980, 1994, 2013). Second, LI can manifest differently across domains in assessment, such as receptive and expressive overall language, vocabulary, and grammar (Calder et al., 2023; Norbury et al., 2016; Tomblin et al., 1997). We note that while LI can influence the use of language for social communication, the underlying difficulties in LI involve structural language and not pragmatics (Andreou et al., 2022). This merits attention to how studies use norm-referenced assessments, which provide an outcome relative to a nationally representative sample of age peers and are commonly used to determine service eligibility in at least the United States for children ages 3 to 21 years who are eligible for special education services (hereafter, school-age; Individuals with Disabilities Education Improvement Act [IDEIA], 2004; Selin et al., 2022). Understanding heterogeneity of structural language requires transparent reporting of approaches to measurement (Koegel et al., 2020).

## Changes in the Diagnostic Criteria of Autism

Although the *Diagnostic and Statistical Manual of Mental Disorders* provides criteria to facilitate reliable diagnoses of autism (Surís et al., 2016), autism as a concept has changed over time (Rosen et al., 2021). Autism first appeared under schizophrenia in the DSM-I (APA, 1952) and DSM-II (APA, 1968). In the DSM-III, autism became an independent diagnosis, amid a pivot from etiological definitions to concrete criteria (Surís et al., 2016). DSM- III criteria specified early onset of a lack of interest in people, gross deficits in language development, peculiar speech patterns, bizarre responses to the environment, and absence of delusions as in schizophrenia (APA, 1980). Early findings documented evidence of structural LI in autism (Bartolucci et al., 1980; Howlin, 1984). The DSM-IV-TR included an early spoken language delay as a criterion in the communication domain for autistic disorder (APA, 1994, 2000). In contrast, the DSM-5 has no communication domain and does not include early language delay as a criterion in the social communication and social interaction domain for autism spectrum disorder; rather, autism includes LI as a specifier (APA, 2013). While the role of a language delay in autism is an ongoing topic of debate (Cirnigliaro et al., 2023), these changes underline a need for precision in reporting structural language benchmarked against diagnostic criteria.

## Characterizing Structural Language

A second consideration in characterizing structural language in autism involves what domains to assess. To our knowledge, there are no population studies of LI in autism. However, there are population studies of LI in nonautistic youth, which have a more significant “weight of the evidence,” as they draw from samples representative of the population (versus a convenience sample which may not be representative). Findings from both the autism literature and these population studies support assessment of nonverbal intelligence (NVIQ), speech sound production, and of multiple language domains.

### *Nonverbal Intelligence*

Findings from autism support no one-to-one correspondence between language impairment and NVIQ, including those who are minimally speaking (Munson et al., 2008; Slušná et al., 2021) and those with language impairment (Girolamo et al., 2022). Some samples have shown a "radical dissociation" between language and NVIQ in nonverbal and minimally speaking autistic individuals (Munson et al., 2008; Slušná et al., 2021). A meta-analysis of 54 studies tracking language outcomes in autistic individuals ages 17 months to 38 years found IQ did not moderate language outcomes or language growth (Brignell et al., 2018). Some nonspeaking and minimally speaking autistic individuals have age-appropriate range NVIQ, suggesting that language impairment in autism cannot be fully explained by intellectual disability (Slušná et al., 2021).

Population studies of LI in nonautistic children also do not support a universal cooccurrence between structural language skills and NVIQ. Tomblin and colleagues (1996) used a cutoff of NVIQ ≥ 87 to ascertain kindergartners with specific LI, with the cutoff indicative of the specificity of difficulties to structural language. Yet, 12% of the sample had an NVIQ below this cutoff and typical language (Rice, 2017; Tomblin et al., 1997). Norbury and colleagues (2016) examined language outcomes in children (ages 4-5) with LI, finding no difference in children whether NVIQ was within -1 *SD* or -1 to -2 *SD*. The only difference was that children with NVIQ < 70 performed lower on overall production but not the four other composite scores (Norbury et al., 2016). Thus, LI in autistic and nonautistic youth can dissociate with NVIQ.

### *Speech Sound Production*

Structural language difficulties and speech sound disorders can co-occur (Shriberg et al., 1999), and each can cause expressive disruptions in fluency (Zhang & Tomblin, 2000). Yet, the ability to produce speech sounds required for language assessment may be due to limitations in articulation, which comprise one aspect of speech sound development, or phonology; this ability is distinct from structural language skills (Dodd et al., 2018; Fey, 1982).

In 42 autistic youth ages 4 to 7 years without intellectual disability, the mean percent consonants correct on a measure of syllable repetition was nearly 92%; however, 17% showed a speech delay (Shriberg & Mabie, 2017; Shriberg et al., 2011). In population studies of LI in nonautistic youth, 5% to 8% of those with specific LI over age 9 have shown a speech delay (Shriberg et al., 1999; Tomblin et al 1997). A separate study of nonautistic youth found children with LI had lower accuracy than age peers without LI, though all had >95% consonants correct; Norbury et al., 2016). Therefore, speech sound disorder can co-occur with autism and LI.

### *Assessment of Structural Language Across Domains*

In autism, language skills can vary by language domain. Indeed, autistic individuals (ages 6 to 21) who produce fewer than 20 or 200 spoken words show lexical and morphosyntactic variability (Butler et al., 2023). One possible factor involves the nature of assessment. Relying on tasks that draw on social communication from a neurotypical perspective may not be useful for assessing structural language in autism. For instance, autistic children perform lower on narration tasks than nonautistic peers (Baixauli et al., 2016; Geelhand et al., 2020). Third, assessing NVIQ independent of verbal IQ (VIQ) or full-scale IQ (FSIQ; which includes both NVIQ and VIQ) is important, as LI can conflate difficulties accessing structural language used in cognitive assessment with cognitive abilities. Autistic children (ages 4 to 14) score lower on VIQ versus NVIQ, with a discrepancy of nearly -1 *SD* in LI (Grondhuis et al., 2018). In turn, autism studies vary in whether they use VIQ, NVIQ, or FSIQ (Russell et al., 2019).

Studies of LI in nonautistic youth have found ascertaining LI using two or more of five composite scores to be clinically useful: expressive and receptive vocabulary, expressive and receptive grammar,

expressive and receptive narration, overall comprehension, and overall expression (Norbury et al., 2016; Tomblin et al., 1996). Yet, in a third population study, Calder and colleagues (2023) found that individual measures were inconsistent in their ability to identify LI. Children with LI had scores within age expectations on a norm-referenced measure of receptive vocabulary, and only some Clinical Evaluation of Language Fundamentals-3rd Ed. (CELF-3; Semel et al., 1995) subtests predicted LI: Semantic Relationships, Recalling Sentences, and Sentence Assembly (Calder et al., 2023). Altogether, findings support the use of multi-domain assessment versus relying on a single domain to profile language.

### *Summary*

Prior studies of LI support assessment of NVIQ, speech sound production, and multidomain language assessment in characterizing structural language (Calder et al., 2023; Norbury et al., 2016; Tomblin et al., 1997). Together with findings in autism, this approach aligns to recent calls to appreciate linguistic heterogeneity across the autism spectrum rather than forming coarse groupings of typical language, LI, or minimally speaking individuals (Schaeffer et al., 2023).

## Impact of Assessment on Access to Supports

A third consideration in characterizing structural language in autism pertains to understanding the assessments studies use; this process has significant real-world implications. In the United States, assessment often serves as the point of access to supports for school-age children (Adlof & Hogan, 2019; IDEIA, 2004). Within this system, U.S.-based speech-language pathologists report that norm-referenced assessments are frequently part of the eligibility criteria for services and that they use a cutoff on one or two assessments to determine eligibility (Selin et al., 2022). Commonly used measures include assessments of overall receptive-expressive language or vocabulary, namely the CELF (Semel et al., 2003), Preschool Language Scale-4th ed. (PLS-4; Zimmerman et al., 2003), Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 2007), and Expressive One-Word Picture Vocabulary Test (EOWPVT; Brownell, 2000; Betz et al., 2013). Yet, studies of LI in non-autistic individuals do not consistently use validated assessments, instead relying on assessments without evidence-based cut scores that maximize diagnostic accuracy of structural language difficulties (Nitido & Plante, 2020). Understanding how research assesses structural language in autism is important for informing evidence-based practice, including assessment, that provides access to services and supports.

Post-DSM-5, the Office of Special Education and Rehabilitative Services of the United States Department of Education issued a letter identifying concerns that a growing number of autistic children are failing to receive appropriate services to address their communication needs (Musgrove, 2015). Specifically, special education programs were not providing speech-language pathology services to autistic children or including speech-language pathologists in assessment or eligibility determinations (Musgrove, 2015). This letter contrasts with pre-DSM-5 data. Analysis of the National Longitudinal Transition Survey-2, a 10-year longitudinal study of a nationally representative sample of students with disabilities from 2000 to 2009, found 75% of autistic youth in their last year of high school received speech-language therapy or communication services (Newland et al., 2011). Since a language delay including LI is no longer an eligibility criterion for diagnosis of autism, autistic children may face reduced access to assessment and services to meet their communication needs.

## The Current Study

Amid diagnostic changes in autism, it is critical to understand how studies report normreferenced outcomes when considering the linguistic dimensions pertaining to structural language and LI. To address this gap, this systematic review aimed to characterize studies in school-age autistic individuals that used norm-referenced measures for linguistic domains pertaining to LI. We asked:

1. What are the patterns of reporting of variables, namely clinical diagnosis, language groups, speech sound production, overall receptive-expressive language, vocabulary, grammar, and NVIQ, relevant to LI in ASD prior to and after publication of the DSM-5?
2. What norm-referenced assessments does the research literature use to characterize the language abilities of autistic individuals with respect to LI?

## Method

This systematic review was preregistered with PROSPERO (CRD42021260394). We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses protocol (Page et al., 2021).

### Search Procedures

The third author conducted database searches on September 20, 2022. Prior to the searches, the third author searched for existing relevant reviews and protocols to avoid redundancy: *Cochrane Database of Systematic Reviews*, *Campbell Systematic Reviews*, *JBI Evidence Synthesis*, and ProQuest PsycINFO. Next, we reviewed test searches and used key articles to determine efficacy before finalizing the search strategy. The search included the following databases: PubMed, PsycINFO, ProQuest Linguistics and Language Behavior Abstracts. To reduce publication bias and identify grey literature, the search also included the Directory of Open Access Journals. The final search included terms related to three essential concepts without limits on language or publication year: autism, language, and age; see Appendix. Search results were uploaded into Covidence (Veritas Health Innovation, 2021), which automatically removed duplicate records. The first and second authors independently screened titles and abstracts and full texts, discussing agreements until they reached consensus.

### Selection Criteria

This review included empirical studies published between 1980 (i.e., when autism became an independent diagnosis) to 2021 in English. We also included studies primarily involving evaluation of dimensions of language relevant to LI (overall expressive-receptive language, vocabulary, speech sound production, and morphosyntax) and using at least one normreferenced assessment. Finally, this review included studies with at least one individual age 3 to 21 with a diagnosis of autism, with no exclusion of co-occurring diagnoses (e.g., fragile X syndrome). This age-range coincides with eligibility for school-based special education services, where children become eligible in the year they turn three (IDEIA, 2004). Furthermore, as studies often only included group-level data, excluding individual participants out of this age range was impossible. We also excluded studies that focused on areas other than assessment (e.g., intervention or neuroimaging) or on dimensions of language that are not structural language (e.g., pragmatics). Finally, this review excluded studies using only experimental measures, or assessments in other languages or specific variants of English (e.g., British English), as language communities differ in their use of language and norms.

### Quality Review

This review appraised bias in studies reporting using one or more norm-referenced measures to evaluate structural language and related areas (e.g., speech sound production, cognitive ability). Here we considered systematic error from the truth in the presentation of results. Because Cochrane (2022) has no risk of bias tool ready for implementation in systematic reviews of observational, non-intervention studies, we considered the quality of reporting for internal validity and completeness of reporting (Viswanathan et al., 2012). Internal validity included whether studies assessed language abilities across domains relevant to LI in autism. Completeness of reporting entailed: a) whether studies provided sufficient information about participants, including clinical diagnosis, NVIQ, and any relevant definitions for grouping, to interpret the findings, and b) whether studies selectively reported outcome measures

rather than reporting all outcomes. Studies with the following characteristics received a high-quality rating:

a. Sample size: studies with autistic participants $n \geq 20$, following estimates for power analysis for speech-language pathology (Gaeta & Brydges, 2020);
b. Selective outcome reporting: studies providing information on all participant outcomes or stating that participants were excluded for reasons unrelated to performance (e.g., attrition). An example of selective outcome reporting is a study post-hoc excluding participants who impact results in a way the authors did not intend as outliers. Such exclusion without explanation of how results and inferences differed would bias results;
c. Clinical diagnosis: studies providing a specific diagnostic label, such as "DSM-5 autism," or a reference to the version of DSM used;
d. Grouping: studies providing an operational definition for grouping of autistic participants (e.g., minimally speaking), when applicable. While some support moving away from such grouping (Schaeffer et al., 2023), operational definitions for groups provide precision in understanding participant characteristics (Koegel et al., 2020);
e. NVIQ: studies providing NVIQ, and not just VIQ or FSIQ, which can yield scores nearly 1 *SD* lower than NVIQ in autistic individuals with LI (Grondhuis et al., 2018);
f. Speech sound production: studies providing information about articulation and phonological abilities that confirm the ability to produce speech sounds for language assessment (Zhang & Tomblin, 2000);
g. Overall language ability: studies providing information about overall expressivereceptive language ability. Here we considered composite scores and did not appraise studies by whether they provided domain or subtest scores;
h. Grammar: studies providing information about grammar abilities (expressive, receptive, or both);
i. Vocabulary ability: studies providing information on vocabulary abilities (expressive, receptive, or both).

### Data Extraction and Synthesis

The authors analyzed studies in terms of participants, assessments, and findings. To describe the language variables reported in studies, the first author and second author extracted and synthesized data in Covidence (Veritas Health Innovation, 2021), discussing disagreements until they reached consensus. The authors extracted information on age, population, sample size, cutoff for LI, provision of information on IQ, domains of language assessed, and results. The authors also compiled information on measures of speech sound production, vocabulary, grammar, overall language, and IQ. Comparisons in reporting patterns across pre-DSM-5 (DSMIII, DSM-IV-TR) and post-DSM-5 studies used descriptive analyses (e.g., frequencies, chisquare tests of homogeneity when sample size was sufficient and Fisher's exact test when $n < 5$) with an *a priori* significance value of $p < .05$ (Blalock, 1972; Marascuilo & McSweeney, 1977).

### Community Involvement

This systematic review included external reviewers varying in their relationship to autism research and practice. The research team included autistic individuals who supported the publication and dissemination of this review.

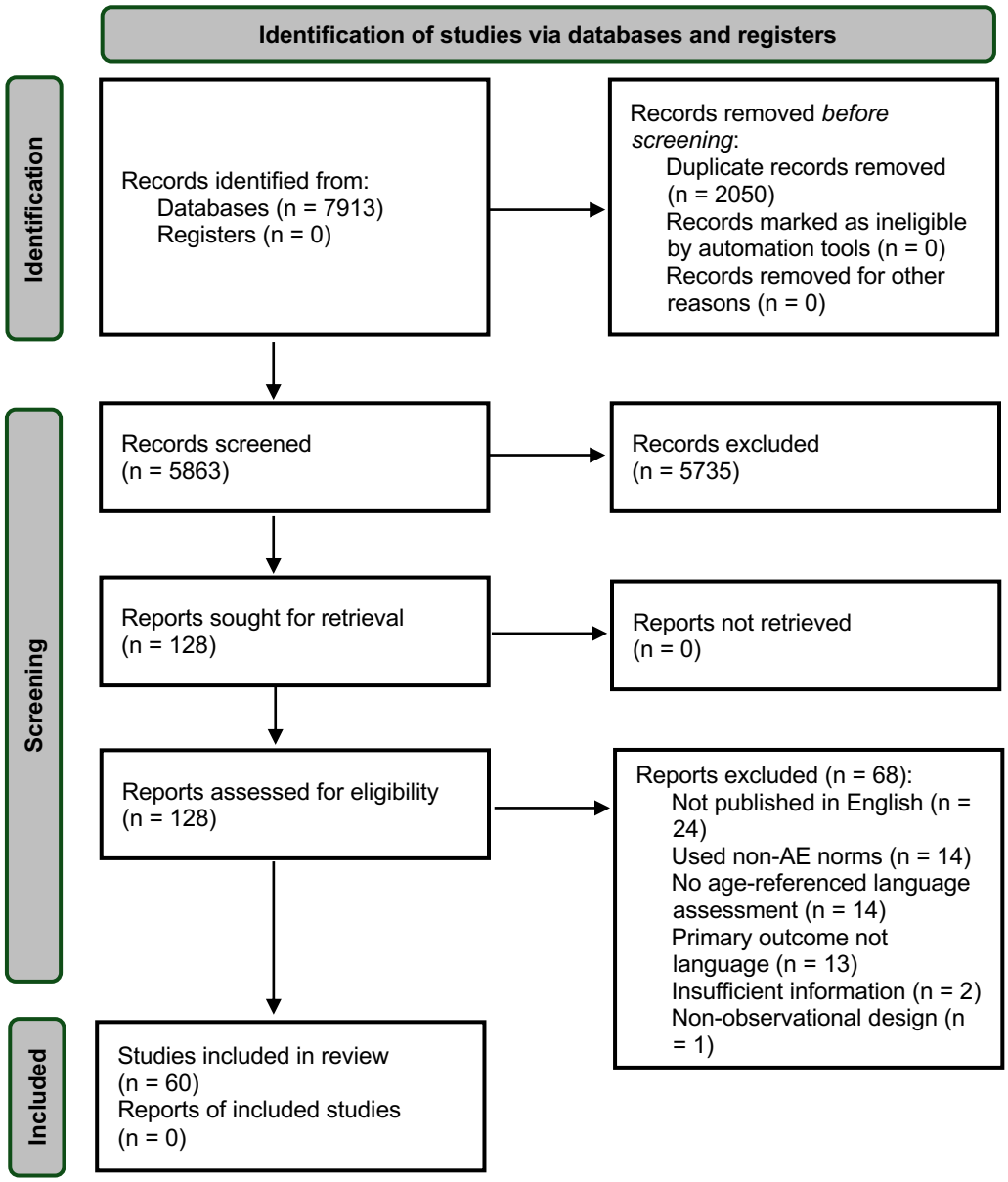
## Results

### Study Selection

Searches yielded 7913 results from databases; see Figure 1. After removing 2051 duplicates, screening 5862 studies' titles and abstracts led to the exclusion of 5735 studies. The remaining 127 studies were assessed for full-text eligibility, with exclusion for various reasons: published in a language

other than English ($n$ = 24), used language measures with norms other than American English (e.g., Australian or British English; $n$ = 14), no use of norm-referenced language assessments (i.e., experimental measures only; $n$ = 14), primary outcome other than language (e.g., neuroimaging; $n$ = 13), insufficient information for inclusion (e.g., no inclusion of diagnostic labels; $n$ = 2), non-observational study design (e.g., intervention; $n$ = 1), and wrong age range (e.g., < 3 years; $n$ = 2). The 57 studies that qualified for the review included 7915 autistic individuals, with sample sizes ranging from 1 to 2047 participants. However, participants were not all unique. For instance, some came from larger samples or longitudinal studies; Ellis Weismer et al., 2010, report that about one-third of participants overlapped with Luyster et al., 2007). Of all 57 studies, 36 (63%) used pre-DSM-5 criteria or were published prior to the DSM-
5, with one DSM-III study, 34 DSM-IV-TR studies, and 22 DSM-5 studies.

Figure 1. PRISMA flow chart of searches of databases and other sources (Page et al., 2021).



## Quality Analysis: Reporting Practices Prior to and After the DSM-5

To address our first research question, we rated reporting of variables relevant to LI in autism pre- and post-DSM-5. For a summary of the quality analysis, see Table 1. Because ratings for pre- and post-DSM-5 studies did not differ on any criteria except clinical diagnosis, we report frequencies for the entire sample; exact frequencies are in Table 2.

**Table 1.**

*Quality Analysis of Studies Reporting Use of Age-Referenced Measures to Assess Structural Language in Autism*

| Reference | *N* | Reporting | Dx Group | NVIQ | Artic/Sp | Overall | Grammar | Vocab |
|---|---|---|---|---|---|---|---|---|
| **DSM-III/DSM-III-R** | | | | | | | | |
| Rapin et al. (2009) **DSM-IV/DSM-IV-TR** | 118 | Low | High | High | High | High | High | Low | High |
| Anderson et al. (2007) | 98 | High | High | N/A | High | Low | High | Low | Low |
| Bal et al. (2020) | 267 | High | Low | High | High | Low | High | Low | Low |
| Bennett et al. (2008) | 64 | High | High | High | High | Low | Low | High | Low |
| Bennett et al. (2014) | 330 | High | High | High | Low | Low | High | Low | Low |
| Botting & Conti-Ramsden (2003) | 13 | High | High | High | High | Low | High | High | High |
| Charman et al. (2003) | 134 | High | High | N/A | High | Low | Low | Low | High |
| Condouris et al. (2003) | 44 | High | High | High | High | Low | High | High | High |
| Eigsti et al. (2007) | 16 | High | High | High | High | Low | Low | Low | High |
| Eigsti & Bennetto (2009) | 21 | High | High | High | High | Low | Low | Low | High |
| Ellawadi & Ellis Weismer (2015) | 105 | High | High | High | High | Low | High | Low | Low |
| Ellis Weismer & Kover (2015) | 129 | High | High | High | High | Low | High | Low | High |
| Ellis Weismer et al. (2010) | 257 | High | High | N/A | High | Low | High | Low | Low |
| Ellis Weismer et al. (2011) | 40 | High | High | N/A | High | Low | Low | High | High |
| Gagnon et al. (2021) | 2047 | High | High | High | High | Low | High | Low | High |
| Hartley et al. (2008) | 53 | High | High | N/A | High | Low | High | Low | Low |
| Jyotishi et al. (2017) | 20 | High | Low | High | High | Low | High | Low | High |
| Kjelgaard & Tager-Flusberg (2001) | 89 | High | High | High | High | High | High | Low | High |
| Kover & Ellis-Weismer (2014) | 57 | High | High | N/A | High | Low | Low | Low | High |
| Kover et al. (2013) | 49 | High | Low | N/A | High | Low | Low | Low | High |
| Landa & Goldberg (2005) | 19 | High | Low | High | High | Low | Low | High | Low |
| Lindgren et al. (2009) | 52 | High | Low | High | High | Low | High | Low | High |
| Luyster et al. (2007) | 93 | High | Low | N/A | High | Low | Low | Low | High |
| McGregor et al. (2012) | 33 | High | Low | High | High | Low | High | High | High |
| Minshew et al. (1995) | 62 | High | High | High | High | Low | Low | Low | Low |
| Modyanova et al. (2017) | 83 | Low | High | High | High | High | Low | High | High |
| Paul et al. (2008) | 37 | High | High | N/A | High | Low | High | Low | High |
| Perovic et al. (2013) | 48 | High | High | High | High | Low | Low | High | High |
| Prescott & Ellis Weismer (2022) | 126 | High | High | High | High | Low | High | Low | Low |
| Riley et al. (2019) | 24 | High | High | N/A | High | Low | High | Low | Low |
| Roberts et al. (2004) | 62 | High | High | High | High | High | Low | High | High |
| Thurm et al. (2007) | 59 | High | Low | N/A | High | Low | High | Low | High |
| Thurm et al. (2015) | 70 | High | High | High | High | Low | High | Low | Low |
| Volden et al. (2011) | 294 | High | High | N/A | High | Low | High | Low | Low |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Whitehouse et al. (2008) | 34 | High | High | High | High | High | High | High | Low |
| Worth & Reynolds (2008) | 1 | High | Low | Low | Low | Low | High | High | Low |
| Woynaroski et al. (2016) | 87 | High | High | High | Low | Low | High | Low | High |
| **DSM-5** | | | | | | | | | |
| Bal et al. (2016) | 1470 | High | Low | High | High | Low | High | Low | Low |
| Biller & Johnson (2020) | 1 | High | High | High | High | High | High | Low | High |
| Broome et al. (2022) | 22 | High | High | N/A | High | High | High | Low | High |
| Broome et al. (2021) | 23 | High | High | N/A | High | High | High | Low | High |
| Burton et al. (2020) | 16 | High | High | High | High | Low | High | High | Low |
| Girolamo et al. (2020) | 10 | High | Low | Low | High | High | High | High | Low |
| Girolamo & Rice (2022) | 13 | High | High | High | High | High | High | High | High |
| Haebig & Sterling (2017) | 50 | High | Low | N/A | High | Low | Low | Low | High |
| Hart & Curtin (2021) | 20 | Low | High | N/A | Low | Low | Low | Low | High |
| Huang & Finestack (2020) | 15 | High | Low | High | High | Low | High | High | Low |
| Jiménez et al. (2021) | 118 | High | Low | High | High | Low | Low | Low | High |
| Jokel et al. (2021) | 21 | High | High | Low | High | Low | High | Low | Low |
| Klusek et al. (2014) | 67 | High | Low | N/A | High | Low | Low | Low | High |
| Kover et al. (2014) | 45 | High | Low | N/A | High | Low | Low | High | High |
| Nadig & Mulligan (2017) | 9 | High | Low | N/A | High | Low | High | Low | Low |

**Table 2.**

*Proportions of Studies Receiving High-Quality Ratings per Criterion Pre- and Post-DSM-5*

| **Criterion** | **Pre-DSM-5** (*n*=35) | | **Post-DSM-5** (*n*=22) | | **Total** (*n*=57) | | *p* |
|---|---|---|---|---|---|---|---|
| | *n* | % | *n* | % | *n* | % | |
| autism sample size | 31 | 88.6 | 15 | 68.2 | 46 | 80.7 | .086 |
| selective outcome reporting | 33 | 94.3 | 22 | 100.0 | 55 | 96.5 | .518 |
| clinical diagnosis | **27** | **77.1** | **10** | **45.5** | **37** | **64.9** | **.015** |
| grouping* | 19 | 86.4 | 9 | 90.0 | 28 | 87.5 | 1.000 |
| NVIQ | 31 | 88.6 | 21 | 95.5 | 52 | 91.2 | .639 |
| articulation/speech | 5 | 14.3 | 6 | 27.3 | 11 | 19.3 | .305 |
| overall language ability | 21 | 60.0 | 15 | 68.2 | 36 | 63.2 | .533 |
| grammar | 12 | 34.3 | 6 | 27.3 | 18 | 31.6 | .579 |
| vocabulary | 21 | 60.0 | 13 | 59.1 | 34 | 59.6 | .946 |

*Note.* Significant differences in bolded text. DSM-III study not reported separately, as there was one DSM-III study and 35 DSM-IV studies. Sample size, selective outcome reporting, NVIQ, articulation and speech, and grammar used Fisher's exact test due to small sample size. Clinical diagnosis, overall language ability and vocabulary used chi-square tests of homogeneity.

*Total *n* for grouping = 32. Pre-DSM-5 studies that used grouping criteria *n* = 22, and post-DSM-5 studies that used grouping criteria *n* = 10.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Nevill et al. (2019) | 104 | High | High | N/A | High | Low | High | Low | Low |
| Plesa-Skwerer et al. (2016) | 19 | High | Low | High | High | Low | High | Low | High |
| Reinhartsen et al. (2019) | 695 | High | Low | N/A | High | Low | High | Low | Low |
| Sterling (2018) | 37 | High | Low | N/A | High | High | Low | High | High |
| Thurman & Hoyos (2020) | 25 | High | Low | High | High | Low | High | Low | High |

*Note.* Reporting = complete reporting of outcomes. Dx = reported clinical diagnostic label. Group = provided an operational definition for grouping when applicable. NVIQ = used age-referenced nonverbal intelligence measure. Artic/Sp = used age-referenced articulation/speech measure. Overall = used age-referenced overall language measure. Grammar = used age-referenced grammar measure. Vocab = used age-referenced vocabulary measure. High = autistic $N \geq 20$; complete outcome reporting; provided a specific diagnostic label; provided an operational definition for grouping autistic participants; provided NVIQ; provided information about articulation and speech abilities; provided information about overall expressive-receptive language ability; provided information about grammar abilities; provided information about vocabulary abilities. Low = autistic $N < 20$; selective outcome reporting (e.g., excluding participants who impacted results in a way the authors did not intend as outliers); did not provide a specific diagnostic label; did not provide an operational definition for grouping autistic participants; did not provide NVIQ; did not provide information about articulation and speech abilities; did not provide information about overall expressive-receptive language ability; did not provide information about grammar abilities; did not provide information about vocabulary abilities. N/A = not applicable. DSM-III/III-R/IV/IV-TR/5 = Diagnostic and statistical manual of mental disorders-3rd/3rd-revised/4th/4th-text revision-5th edition (American Psychiatric Association,
1980, 1987, 1994, 2000, 2013). Broome et al. (2021, 2022) and Jokel et al. (2021) included participants with a DSM-4 or DSM-5 diagnosis of ASD. Minshew et al. (1995) included participants with a DSM-III-R/DSM-IV diagnosis.

### *Sample Size and Selective Outcome Reporting*

Forty-six of 57 (81%) of studies received high-quality ratings for sample size. Of the 11 studies that received low-quality ratings, nine (82%) had samples of $N < 20$, and two (18%) were case studies. Nearly all studies (55 of 57, or 97%) received high-quality ratings for selective outcome reporting, though some studies may not have reported exclusion. One DSM-IV study mentioned exclusion of 14 participants who had borderline LI and did not meet selection criteria for autism with or without LI (Modyanova et al., 2017). The one DSM-III-R study excluded data from 20 of 82 children who scored at floor on language measures (Rapin et al., 2009).

### *Clinical Diagnosis*

Most studies (37 of 57, or 65%) received high-quality ratings for diagnostic information, but the expected proportion of studies receiving high-quality ratings differed by DSM version. Pre-DSM-5 studies (27 of 35, or 77%) were more likely to receive a high-quality rating than post-DSM-5 studies (10 of 22, or 46%), $p = .015$. Studies also differed in the DSM versions they used to characterize participants: DSM-III-R ($n = 1$), DSM-III-R or DSM-IV ($n = 1$), DSM-IV ($n = 23$; 14 DSM-IV and 9 DSM-IV-TR), and DSM-5 ($n = 7$); see Supplementary Table 1.

**ASD.** A majority of studies reported ASD as a diagnostic label ($n = 36$ of 57, or 63%). However, DSM-5 studies (21 of 22, or 96%) were more likely to report ASD as a diagnostic label than DSM-III or DSM-IV studies (15 of 35, or 43%), $p < .001$. Note that while DSM-5 studies used ASD as an umbrella diagnosis, DSM-IV studies varied in definitions of ASD. For instance, Paul and colleagues (2008) defined ASD as inclusive of autism and PDD-NOS; in contrast, Anderson and colleagues (2007) treated ASD and PDD-NOS as separate groups. Further, while all DSM-5 studies used DSM-5 criteria to confirm diagnosis, six (27%) reported DSM-IV diagnoses now included under ASD: Asperger syndrome ($n = 2$), autistic disorder ($n = 1$), and PDD-NOS ($n = 4$). These differences in reporting impact the consistency of reporting participant characteristics across studies.

**ASD plus Co-occurring Genetic Conditions**. Few studies reported ASD plus cooccurring genetic conditions regardless of pre- or post-DSM-5 status ($n = 4$, or 7%). No preDSM-5 study reported such diagnoses versus four DSM-5 studies (18%) that reported ASD plus either fragile X syndrome ($n = 3$) or "chromosomal abnormalities" ($n = 1$), $p = .019$. Though

further discussion is beyond the scope of this report, the recency of genetic testing and creation of a fragile X participant database may contribute to this difference (Sherman et al., 2017).

**Autistic Disorder.** Few studies reported autistic disorder. Eight of 35 (23%) pre-DSM-5 studies reported autistic disorder compared to one of 22 (5%) post-DSM-5 studies; this difference was not significant. While autistic disorder is not a DSM-5 diagnosis, some DSM-5 studies analyzed data from databases with data collected prior to the DSM-5. In turn, in studies using DSM-III-R criteria, autistic disorder would be the only possible diagnosis (e.g., Minshew et al., 1995; Rapin et al., 1995). Appreciating these differences in how samples were originally ascertained is relevant for understanding who comprises the evidence base.

**Asperger syndrome.** Like autistic disorder, few studies reported Asperger syndrome, a diagnosis that only existed in the DSM-IV-TR. Four of 35 pre-DSM-5 studies (11%; all DSM-IV studies) included Asperger syndrome compared to two DSM-5 studies (9%). This difference was not significant. Studies varied in how they operationalized this term. While acknowledging that DSM-IV criteria stated a child with Asperger syndrome who met criteria for autism would receive a diagnosis of autism, Bennett and colleagues (2008) differentiated Asperger syndrome and "high-functioning autism" on the basis of having an early, significant language delay. In general, pre-DSM-5 studies likely assumed that individuals with Asperger syndrome would have age-appropriate and unimpaired language abilities.

**Autism.** Pre-DSM-5 studies were more likely than DSM-5 studies to report autism as a diagnostic label, with the caveat that studies differed in their use of the term. For instance, autism may be an umbrella term or refer to a specific diagnosis, such as autistic disorder (autism) in the DSM-IV. While no DSM-III-R study referred to autism, 14 DSM-IV studies (40%) did compared to 2 of 22 (9%) DSM-5 study; this difference was statistically significant, $p = .011$.
Many studies used research definitions and instruments that refer to "autism" (see Supplementary Table 1) to qualify participants. Yet, they were not uniform in clearly stating whether autism was tied to a specific instrument, clinical cutoff, or detailed evaluation.

**PDD-NOS.** Studies did not differ in rates of reported inclusion of PDD-NOS ($n = 13$, or 23%). Nine of 35 DSM-IV studies (26%) reported PDD-NOS compared to four of 22 (18%) DSM-5 studies; this difference was not significant.

**Summary.** Differences in diagnostic labels paralleled changes in the DSM, from autistic disorder in the DSM-III-R study to autistic disorder and related diagnoses in DSM-IV studies to ASD in DSM-5 studies. Transparency in reporting diagnostic labels is key for enhancing the accessibility of research findings.

### *Grouping*

We analyzed grouping criteria relevant to language. Of the 32 studies that used grouping criteria, 28 (88%) received a high-quality rating. Studies focused on four groups with no differences in the expected proportion of studies per group: autism without further specifiers ($n = 28$, or 49%), autism plus language impairment ($n = 14$, or 25%), "high functioning autism" ($n = 6$, or 11%), and minimally speaking ($n = 5$, or 9%); see Table 3 for frequencies and Supplementary Table 2 for details.

**Table 3.**

*Frequencies of Diagnostic Labels, Groups, Cognitive Abilities, and Language Domains Assessed*

*Note.* Significant differences in bolded text. Full scale/overall = verbal plus nonverbal together. ASD + genetic diagnoses, Asperger syndrome, autistic disorder, "high functioning" autism, minimally speaking, nonverbal cognitive ability, full scale/overall cognitive ability, articulation/speech, expressive grammar, and receptive grammar used Fisher's exact test due to small sample size. ASD, Autism, PDD-NOS, autism – no specifiers, autism + language impairment, verbal cognitive ability, overall receptive, overall expressive, receptive vocabulary, and expressive vocabulary used chi-square tests of homogeneity.

| | Pre-DSM-5 (*n*=35) | | Post-DSM-5 (*n*=22) | | total (*n*=57) | | *p* |
|---|---|---|---|---|---|---|---|
| | *n* | % | *n* | % | *n* | % | |
| **Diagnostic Labels** | | | | | | | |
| ASD | **15** | **42.9** | **21** | **95.5** | **36** | **63.2** | **<.001** |
| ASD + genetic diagnoses | **0** | **0.0** | **4** | **18.2** | **4** | **7.0** | **.019** |
| Asperger syndrome | 4 | 11.4 | 2 | 9.1 | 6 | 10.5 | 1.000 |
| autism | **14** | **40.0** | **2** | **9.1** | **16** | **28.1** | **.011** |
| autistic disorder | 8 | 22.9 | 1 | 4.5 | 9 | 15.8 | .132 |
| PDD-NOS | 9 | 25.7 | 4 | 18.2 | 13 | 22.8 | .509 |
| **Grouping** | | | | | | | |
| Autism - no specifiers | 18 | 51.4 | 10 | 45.5 | 28 | 49.1 | .661 |
| Autism + language impairment | 10 | 28.6 | 4 | 18.2 | 14 | 24.6 | .375 |
| "High functioning" autism | 5 | 14.3 | 1 | 4.5 | 6 | 10.5 | .389 |
| Minimally speaking | 2 | 5.7 | 3 | 13.6 | 5 | 8.8 | .364 |
| **Cognitive Ability** | | | | | | | |
| Nonverbal | 30 | 85.7 | 19 | 86.4 | 49 | 86.0 | 1.000 |
| Verbal | 11 | 31.4 | 2 | 9.1 | 13 | 22.8 | .050 |
| Full Scale/Overall | **10** | **28.6** | **1** | **4.5** | **11** | **19.3** | **.037** |
| **Language Domains** | | | | | | | |
| Articulation/Speech | 5 | 14.3 | 7 | 31.8 | 12 | 21.1 | .181 |
| Expressive Grammar | 7 | 20.0 | 5 | 22.7 | 12 | 21.1 | 1.000 |
| Receptive Grammar | 6 | 17.1 | 4 | 18.2 | 10 | 17.5 | 1.000 |
| Overall Receptive | 19 | 54.3 | 16 | 72.7 | 35 | 61.4 | .164 |
| Overall Expressive | 21 | 60.0 | 14 | 63.6 | 35 | 61.4 | .784 |
| Receptive Vocabulary | 18 | 51.4 | 11 | 50.0 | 29 | 50.9 | .916 |
| Expressive Vocabulary | 15 | 42.9 | 12 | 54.5 | 27 | 47.4 | .390 |

**Autism.** Most studies focused on language in autism broadly (*n* = 28, or 49%). These studies included 18 pre-DSM-5 studies (one DSM-III-R, 17 DSM-IV; 51%) and 10 DSM-5 studies (46%); this difference was not significant. Though these studies did not use specifiers, some used grouping criteria to profile language in individuals ages 3 to 18, including one DSM-

III-R study, four DSM-IV studies, and one DSM-5 study.

Pre-DSM-5 studies typically grouped participants to characterize developmental trajectories. The one qualifying DSM-III-R study assessed multiple domains of language and used these assessments to group participants by language profiles; however, the study did not operationally define each of the language profiles: mixed receptive-expressive language disorders, higher-order language processing disorders, and expressive phonology with or without grammar disorders (Rapin et al., 2009). Two DSM-IV studies grouped participants on the basis of early language and communicative regression (Gagnon et al., 2021; Prescott & Ellis Weismer, 2022), and an additional two grouped participants by language level: (a) low language, or being administered ADOS Module 1 (Lord et al., 2000), and an overall receptive-expressive language standard score of 50 or below (Ellis Weismer & Kover, 2015); and (b) spoken language benchmarks in children using age-equivalent scores on an overall receptive-expressive language assessment of less than 15 months for prelinguistic, 15 to 23 months for first words, 24 to 35 months for word combinations, and over 35 months for sentences (Ellawadi & Ellis Weismer, 2015). The one DSM-5 study that grouped participants defined "high verbal" as within -1 *SD* or higher and "mid-verbal" as -1 *SD* or lower on an expressive language measure (Jyotishi et al., 2017). Overall, only some of these definitions focus on structural language.

**Autism Plus Language Impairment.** One quarter of studies explicitly examined the cooccurrence of LI and autism, with no significant differences by DSM version: 10 (29%) DSM-IV studies and four (18%) DSM-5 studies. Studies used 10 different definitions and cutoffs that typically spanned -1 to -2 *SD* on one or more language measures in individuals ages 4 to 21.

DSM-IV studies used seven different definitions of LI, with two using a single measure or subtests from one domain: receptive vocabulary at -2 *SD* in individuals (Roberts et al., 2004) or -1 *SD* on sentence production and sentence repetition subtests (McGregor et al., 2012). Other definitions used a cutoff of -2 *SD* on a receptive vocabulary or an overall receptive-expressive language (Kjelgaard & Tager-Flusberg, 2001). Still other definitions referenced multiple specific language domains: (a) <10$^{th}$ percentile on at least two measures of receptive grammar, receptive vocabulary, and expressive vocabulary using a subtest for VIQ from a brief intelligence test (Modyanova et al., 2017; Perovic et al., 2013); (b) <10$^{th}$ percentile on at least two measures of receptive grammar, narration, subtests for sight word and phonemic decoding, overall communication, nonword repetition, and sentence repetition (Whitehouse et al., 2008); (c) expressive vocabulary <10$^{th}$ percentile and receptive grammar <50$^{th}$ percentile (Botting & ContiRamsden, 2003); and (d) history of a language delay and -1 *SD* on an overall receptiveexpressive language or nonword repetition plus VIQ over 50 (Lindgren et al., 2009). Amid these varying definitions, some studies used a minimum IQ for group comparisons (Botting & ContiRamsden, 2003; McGregor et al., 2012; Whitehouse et al., 2008) or treated IQ < 70 as mutually exclusive with LI (Bennett et al., 2008).

DSM-5 studies also tended to define LI using multiple assessments. One study used a cutoff of 95 or below on a norm-referenced expressive grammar test shown to have good sensitivity to LI and NVIQ of at least 70 (Huang & Finestack, 2020). All other DSM-5 definitions included multiple domains: (a) NVIQ of at least 70 plus a standard score at -1.5 *SD* on an overall expressive-receptive language test (Bennett et al., 2014), and (b) -1.25 *SD* on at least two measures of overall language, receptive vocabulary, expressive vocabulary, grammar, and nonword repetition (Girolamo & Rice, 2022). In all, these 10 definitions of LI aligned to studies of LI in non-autistic individuals, with about half restricting LI to NVIQ of >70.

**"High Functioning" Autism.** Six studies examined language in "high functioning" autism ("HFA"); the quotes refer to use of this term in the original reports. Five DSM-IV (14%) studies and one DSM-5 study (5%) reported "HFA," which did not significantly differ. These studies used five different definitions involving IQ in individuals ages 7 to over 18.

Two DSM-IV studies defined "HFA" that included language domains relevant to LI: a) NVIQ of at least 68 or 70 plus an average within -1.5 *SD* on expressive and receptive grammar subtests from an overall receptive-expressive language assessment (Bennett et al., 2008); and b) FSIQ, VIQ, and a receptive vocabulary standard score within -1 *SD* (Eigsti et al., 2009). Other definitions used FSIQ but not language measures: (a) FSIQ over 80 (Landa & Goldberg, 2005), and (b) an early language delay plus VIQ and FSIQ > 70 plus at least a second-grade reading, spelling, and arithmetic level (Minshew et al., 1995). Thus, these pre-DSM-5 definitions of "HFA" mostly considered verbal and nonverbal abilities together.

The one DSM-5 study used a similar approach as in DSM-IV studies to define "HFA": FSIQ of at least 85 and an age equivalent of at least 48 months on a parent report measure of expressive language (Barton et al., 2020). In sum, pre- and post-DSM-5 definitions considered language and cognition together. Using broad measures of language and cognition as proxies for overall abilities does not reflect the full heterogeneity of abilities and unmet needs of individuals across the autism spectrum (Grondhuis et al., 2018; Waizbard-Bartov et al., 2023).

**Minimally Speaking.** Five (9%) studies focused on minimally speaking autistic individuals and used nine different definitions in individuals ages 2 to 21; one study accounted for five of these definitions (Bal et al., 2016). There were no statistically significant differences in the expected proportion of pre-DSM-5 ($n = 2$) and ($n = 3$) DSM-5 studies focusing on this population. This discrepancy in definitions is consistent with prior work (Koegel et al., 2020). Here, we focus on the aspects of language relevant to LI, particularly with regard to vocabulary.

DSM-IV studies used different operational definitions of minimally speaking. Woynaroski and colleagues (2016) used a continuous variable of 20 words or less on the MacArthur-Bates Communicative Developmental Inventories (CDI) Words and Gestures checklist (Fenson et al., 2003) plus no more than five different word roots produced during a 15minute language sample in children who qualified for a diagnosis of ASD ages 2 to 4. Another definition used a categorical approach paired with direct observation, or a rating corresponding to no speech, single words, or occasional phrases on Autism Diagnostic Observation Schedule (ADOS) item A1, or "Overall level of non-echoed spoken language" (Lord et al., 2000; Thurm et al., 2015).

DSM-5 studies also defined minimally speaking using parent report and categorical criteria. These definitions included no use of phrase speech on a daily basis or parent report of fewer than 30 spoken words or phrases (Plesa Skwerer et al., 2016), as well as comparison of minimally speaking status across five instruments: (a) being administered ADOS Module 1 (Bal et al., 2016, 2020; Lord et al., 2000); (b) parent estimate of 25 spoken words or less; (c) expressive language age equivalent of below 18 months per parent report; (d) no functional three-word phrases daily per item 30 of the Autism Diagnostic Interview-Revised (ADI-R; Rutter et al., 2003b), and (e) no use of phrases or sentences per item one of the Social Communication Questionnaire (Bal et al., 2016; Rutter et al., 2003a). Only Biller and Johnson (2020) referenced mental age, defining minimally speaking as parent estimate of 25 spoken words or less and a nonverbal mental age of at least 12 months. In all, it is unclear to what extent such categorical criteria might collapse variability within the minimally speaking population (Butler et al., 2023).

**Summary.** Overall, pre-DSM-5 and DSM-5 studies were consistent in the broad domains used to define groups: spoken language for minimally speaking, structural language for LI, and FSIQ with or without language measures for "HFA." Yet, because the exact definitions differed, the ability to make direct comparisons across studies is limited.

### *Inclusion of Measures of Nonverbal Cognitive Ability*

Most studies received high-quality ratings for using nonverbal cognitive ability (91%) to characterize participants, with no differences by pre-DSM-5 or DSM-5 status; see Table 2, Table 3, and Supplementary Table 3. Some studies reported more than one type of cognitive measure and did not differ by DSM status in reporting of nonverbal ($n$ = 49, or 86%) or verbal cognitive ability ($n$ = 13, or 23%). There were differences by DSM status, however, in the expected proportion of studies reporting full-scale measures of cognitive ability. Ten (29%) DSM-IV studies versus one (5%) DSM-5 study reported full-scale measures of cognitive ability, $p$ = .037. In all, findings indicate a tendency of studies to align to best practices for use of IQ in autism research (Grondhuis et al., 2018).

### *Use of Measures of Speech Sound Production, Overall Language, Grammar, and Vocabulary*

A majority of studies received high-quality ratings for overall language (63%) and vocabulary (60%), but they were unlikely to report measures of speech sound production (12 of 57, 21%) or specific information on grammar (32%); see Table 3 and Supplementary Table 4. In addition, few studies reported measures of expressive ($n$ = 7, or 20% ) or receptive grammar ($n$ = 6, or 17%), or expressive vocabulary ($n$ = 27, or 47%). In contrast, studies were likely to report overall receptive ($n$ = 35, or 61%) and expressive language ($n$ = 35, or 61%), as well as receptive vocabulary ($n$ = 29, or 51%). While many studies used norm-referenced measures of overall receptive-expressive language, some studies used it as an outcome and did not report actual values, and only some reported specific subtests with information on grammar (e.g., Burton et al., 2020; Worth & Reynolds, 2008).

### *Summary*

Overall, there were nearly no differences in the reporting practices of studies by pre- or post-DSM-5 status. While this analysis does not evaluate the overall quality of study design, inconsistency in reporting of clinical diagnosis and definitions of language groups prevent more fully understanding participant characteristics.

## Use of Norm-referenced Assessments Pre-DSM and DSM-5 Studies

In our second research question, we examined assessments in studies by DSM-5 status. Given that assessments differ in their sensitivity to structural language (Calder et al., 2023) and the heterogeneity of LI across IQ (Norbury et al., 2016), we examined cognitive assessments and language assessments by domain; see Supplementary Table 4 and Figures 1 and 2.

**Cognitive Abilities.** Studies varied in the cognitive measures they used. The most common measure was Mullen Scales of Early Learning (Mullen, 1995; $n$ = 19 of 57, or 33%; 11 pre- and 8 post-DSM-5 studies), followed by a version of the Wechsler Intelligence Scales ($n$ = 14, or 25%): Wechsler Intelligence Scales for Children (Wechsler, 1974, 1991, 2003, 2014; $n$ = 11; 9 pre- and 2 post-DSM-5 studies) or Wechsler Adult Intelligence Scales (Wechsler, 1981, 1997; $n$ = 3; all pre-DSM-5). These assessments benchmark performance against time and require fine motor skills, which precludes accessibility for all autistic students (e.g., Kasari et al., 2013). The third most common measure was the Differential Abilities Scales (Elliott, 1990, 2007; $n$ = 9, or 16%; 10 pre- and 2 post-DSM-5 studies). Eleven studies (19%) reported age equivalent scores or proxies for mental age ($n$ = 6 pre- and 5 post-DSM-5 studies), which is common when standard

scores are unavailable; eight of these studies examined language in early childhood (i.e., upper *M* age = 5 years).

**Speech Sound Production.** In studies reporting measures of articulation and phonology, some limited assessment to the speech errors that confound pronunciation of finiteness-marking in English with finiteness-marking and used the Test of Early Grammatical Impairment phonological probe (Rice & Wexler, 2001; *n* = 1 pre- and 3 post-DSM-5 studies). In this case, studies did not report outcomes other than pass/fail rates, which is the outcome of the probe. Norm-referenced measures that assess articulation and phonology more comprehensively, such as the Goldman Fristoe Test of Articulation (Goldman & Fristoe, 1986; *n* = 2), or speech motor issues, such as the NEPSY oromotor test (Korkman et al., 1988; *n* = 1) and Voice Motor Production Assessment for Children (Hayden & Square, 1999; *n* = 1), were less common.

**Overall Language.** Common measures of receptive-overall language included direct behavioral assessments (versus parent report), such as the Preschool Language Scales (Zimmerman et al., 2002, 2011; *n* = 9, or 16%; 5 pre- and 4 post-DSM-5 studies) and the CELF (Semel et al., 1995, 2003; Wiig et al., 1992, 2013; Zimmerman et al., 2002, 2011; *n* = 14, or 25%). Because these assessments are not designed for all ages or profiles, other common measures, such as for minimally speaking individuals, were more general measures of development. These included the Vineland Adaptive Behavior Scales (Sparrow et al., 2005, 2016; *n* = 12, or 21%; 4 pre- and 8 post-DSM-5 studies), which is a parent report, and the Mullen Scales of Early Learning (Mullen, 1995; *n* = 11, or 19%; 6 pre- and 5 post-DSM-5 studies).

**Receptive and Expressive Vocabulary.** Direct behavioral assessments of vocabulary frequently included a version of the Peabody Picture Vocabulary Test (Dunn, 2019; Dunn & Dunn, 1981, 1997, 2007) for receptive vocabulary (*n* = 20, or 35%; 14 pre- and 6 post-DSM-5 studies) and the Expressive Vocabulary Test (Williams, 1997, 2007, 2019; *n* = 9, or 16%; 4 pre- and 5 post-DSM-5 studies). Some studies used an indirect measure of vocabulary using words understood (*n* = 5 or 9%; 3 pre- and 2 post-DSM-5 studies) or words produced (*n* = 11, or 19%;
5 pre- and 6 post-DSM-5 studies) per parent report on the CDI (Fenson et al., 2007).

**Grammar.** While most studies used a measure of overall language, which includes grammar, few studies used a norm-referenced grammar measure or reported grammar-specific information. Here, measures included the Test of Receptive Grammar (Bishop, 1982, 2003b, 2005; *n* = 5, or 9%; all pre-DSM-5 studies) and the Test of Early Grammatical Impairment (Rice & Wexler, 2001; *n* = 5, or 9%; 2 pre- and 3 post-DSM-5 studies). Less common was indirect assessment via parent report: the Children's Communication Checklist (Bishop, 1998, 2003a; *n* = 2) and grammatical complexity items from the CDI (Fenson et al., 2007; *n* = 1).

### *Summary*

Overall, pre-DSM-5 and DSM-5 studies mostly did not vary in their reporting practices of criteria relevant to structural language in autism. Studies varied more in how they defined groups of participants in terms of clinical diagnosis, language profiles, as well as in reporting of norm-referenced assessment outcomes across language domains and cognitive abilities.

## Discussion

This systematic review identified differences in reporting of information relevant to characterizing structural language in studies of language in autism using one or more normreferenced assessments in school-aged individuals. While previous reviews focused on empirical findings on structural language in autism (Andreou et al., 2022), this review underlines the importance of appreciating consistency in reporting of approaches to assessment.

**Variation in Reporting Practices**

In this review, no study received high-quality ratings across all criteria. While not representative of the quality of study design, these ratings indicate that the approach to characterizing structural language has been piecemeal – both heterogeneous and incomplete. Effectively, this limits the ability to understand sample characteristics. Reporting in terms of exclusion and grouping, as well as diagnostic labels, also has implications for understanding linguistic heterogeneity in autism.

First, few studies reported exclusion of participants, and when they did, it was on the basis of participants showing heterogeneous language abilities versus ones that aligned to grouping criteria. In excluding about one-quarter of 82 participants who scored at floor on normreferenced assessments, Rapin and colleagues (2009) did not report the reason for their performance: inaccessibility, noncompliance, or some other reason. Modyanova and colleagues (2017) similarly excluded 14 of 97 autistic participants who had borderline LI, did not meet criteria for the LI or non-LI group, and were too few in number compared to other groups to create a third group. While appropriate for these individual group designs, such exclusion is consistent with broader trends in autism research. At a systemic level, there is a tendency to focus on groups differentiated by levels of spoken language and structural LI, which perpetuates the masking of linguistic heterogeneity in autism (Schaeffer et al., 2023).

Further, 65% of studies received high-quality ratings for reporting an exact diagnostic label yet differently operationalized the same label. For example, DSM-IV studies varied in whether they included PDD-NOS under ASD (e.g., Anderson et al., 2007; Paul et al., 2008). While many studies independently confirm diagnosis (e.g., with the ADOS, Lord et al., 2000; see Supplementary Table 1), being clear about the exact source of diagnostic labels is important. In this review, 27% of DSM-5 studies that analyzed data from databases, longitudinal studies, and participants who had originally received a DSM-IV diagnosis both independently confirmed diagnosis using DSM-5 criteria and listed the original diagnoses of participants. Providing precise diagnostic information is necessary to understand whether participants were ascertained on the basis of having a language delay, and in turn, how phenotypic variability relates to neurological differences (e.g., autistic or nonautistic with or without LI; Cirnigliaro et al., 2023).

**Variation in Assessments**

As for assessments, findings, which primarily came from United States-based studies, mimicked clinical practice approaches in the United States (Betz et al., 2013). Studies were the most likely to use norm-referenced assessments for overall receptive-expressive language ability (63%) and vocabulary (60%), coinciding with clinician report of most commonly using measures of overall language and vocabulary in practice (Betz et al., 2013). The most commonly used language measures were the: 1) CELF (25% of studies here versus 67% of clinicians using the CELF-4 in practice at least sometimes in Betz et al., 2013; Semel et al., 1995, 2003; Wiig et al., 1992, 2013; Zimmerman et al., 2002, 2011); and 2) Preschool Language Scales (16% of studies here versus 50% of clinicians using the PLS-4 in practice at least sometimes in Betz et al., 2013; Zimmerman et al., 2002, 2011).

In contrast, few studies in this review reported subtests providing information on specific linguistic domains like grammar (which 32% of studies reported). Recall that Calder and colleagues (2023) found that a norm-referenced receptive vocabulary measure overestimated the abilities of nonautistic children with LI and that only some subtests of the Clinical Evaluation of Language Fundamentals-3 (CELF-3; Semel et al., 1995) predicted LI status. The authors used a cut point of -1.5 *SD* on the CELF-3 (Semel et al., 1995) derived from their population mean, as

this test was not normed on Australian children and was published nearly 30 years ago. While every study cannot determine its own population mean, these methods underline the importance of precision in reporting assessments, including interpretation and use. Here, examining the clinical validity of measures was beyond the scope of this review (Nitido & Plante, 2020). Yet, documenting how these measures function across various samples of autistic individuals is crucial to enhancing the quality of the evidence base informing best practices in assessment.

**Recommendations for Reporting**

Given variability in reporting and assessments of studies in this review, one question is how to report information on structural language in autism research. Here, we are guided by realworld implications for autistic individuals. Through our experiences with autistic individuals in research and on our research team, having access to resources to reach their goals is a priority. Access depends on autistic individuals and relevant parties (previously called "stakeholders") having information about norm-referenced language assessments, including how and whether they are meaningful to them. In the real world, autistic youth face disparities in accessing and receiving speech-language services (Taylor and Henninger, 2015). Research may contribute to this disparity, as insufficient transparency in reporting hinders understanding who is and is not included in the evidence base informing development of evidence-based practices, supports, and our understanding of autism. Per Adlof and Hogan (2019), without assessment of all relevant areas of language, it is impossible to holistically understand language.

We call for replicable reporting that allows for full evaluation of linguistic heterogeneity. In a review on definitions of nonverbal and minimally speaking autistic children, Koegel and colleagues (2020) identified several key needs for quality reporting in future intervention studies, including: (a) clearly identifying participant language profiles using systematic assessment, (b) use of norm-referenced receptive-expressive vocabulary and language tests when possible (as some assessments do not have adaptations for individuals who do not use spoken language) along with careful interpretation of the validity of the findings, (c) inclusion of both verbal and nonverbal cognitive ability. We realize that including heterogeneity in studies of structural language in autism when standardized assessments are not developed for nonspeaking or minimally speaking individuals presents unique considerations. Workable solutions might include precisely stating what assessments were empirically shown to be accessible or not to an individual (versus assuming accessibility), using standardized assessments in accessible formats (e.g., touch screen for receptive vocabulary; Plesa Skwerer et al., 2016), and developing more broadly accessible standardized measures, with the idea that measures can be replicable and harmonized across studies versus assuming there is one idealized norm for spoken language development. In addition, while every study clearly did not aim to comprehensively assess the domains of structural language pertaining to LI, studies might consider the following as a start.

Following the spirit of Koegel and colleagues (2020), studies should precisely characterize participants. We take this to entail reporting clear diagnostic information, language subtest outcomes (versus only summary scores), information on when data was collected, and information on to what extent the test norming sample was similar to participants; much of this information aligns to current best practices for reporting. Overall, precision in reporting original work comprises one part of transparency in research reporting. Providing this information is crucial for facilitating understanding of research findings and has real-world relevance for consumers of research within and beyond the ivory tower.

## Limitations

This systematic review had several limitations. First, the search was limited to records in English and outcomes using mostly verbal norm-referenced assessments in English, with no specific variants of English. This exclusion prevents a broader understanding of LI in autistic individuals. Second, our search may have overlooked autistic participants, who, in earlier studies, may have had other diagnoses (e.g., "mental retardation"; Croen et al., 2002). Searches did not include education-focused databases such as ERIC. However, with the preliminary test searches used to develop our strategy, benchmark articles that were not found in PubMed or PsycInfo were found in Linguistic and Language Behavior Abstracts (LLBA). This indicated a potential for expanding the search results, because of the likelihood of more overlap with an education-specific database. Third, focusing on studies that primarily looked at language as an outcome using norm-referenced assessment, versus experimental measures or interventions, may have resulted in overlooking studies that used norm-referenced assessments in the target populations. Yet, evaluating assessment of structural language in these studies would not have been feasible, as they each have different requirements for quality analysis that extend beyond this review. Last, while the search allowed for flagging reports with mentions of "language," it is impossible to estimate the number of papers on autism post-DSM-5 without any information about language.

## Future Research

Our findings highlight directions for further work. Though studies mostly did not differ by DSM version, including reporting practices and frequency of assessments, there is a need to better understand how these approaches to assessing structural language in research align to actual clinical practice. Specific areas in need of clarification are to what extent these approaches are inclusive of the diverse autistic population in terms of test norming (Nitido & Plante, 2020). Further, understanding to what extent interpretation and use of these assessments is relevant to autistic individuals is important. Though beyond the scope of this review, future work should also examine whether autism research post-DSM-5 is as likely to report information on participant language abilities, with the goal of providing advocacy for individuals who may want language supports; this work is underway. Last, it is a question how studies cite structural language in autism studies that use norm-referenced assessments, as that shapes our understanding of autism. For example, Russell and colleagues (2019) found 91% of 187 publications citing original autism studies treated original study findings as being broadly applicable to all autistic individuals, even though 94% of these original studies did not include autistic individuals with intellectual disability (who comprise a significant proportion of the autistic population, with estimates ranging from 38% to 50%; Charman et al., 2011; Loomes et al. 2017; Maenner et al., 2023). There are many more future directions, but these next steps will help strengthen the evidence base and its relevance to autistic individuals.

## Conclusion

In documenting reporting practices prior to and post-DSM-5, this review advocates for greater detail and clarity in reporting of diagnostic labels and language assessment outcomes. Together with exclusion of racially and ethnically minoritized autistic individuals in research (Girolamo et al., 2023), there is a need to critically evaluate findings on language in autistic individuals across the spectrum, lifespan, and walks of life.

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# Appendix

## Search Strategies

ProQuest Linguistics and Language Behavior Abstracts (LLBA):

(MAINSUBJECT.EXPLODE("Preschool Children") OR MAINSUBJECT("Elementary School Students") OR MAINSUBJECT.EXPLODE("Junior High School Students") OR MAINSUBJECT.EXPLODE("High School Students") OR MAINSUBJECT.EXPLODE("College Students") OR MAINSUBJECT.EXPLODE("Adolescents") OR MAINSUBJECT("Secondary School Students") OR MAINSUBJECT("Young Adults") OR MAINSUBJECT("Children") OR ab(child*) OR ab(preschool* or pre-school*) OR ab(toddler*) OR ab("school child" OR "schoolchild") OR ab(youngster*) OR ab(juvenil*) OR ab(kids*) OR (noft(41or) AND ab(kindergarten)) OR noft("" first grader* "" OR "" second grader* "" OR "" third grader* "" OR "" fourth grader* "" OR "" fifth grader* "" OR "" sixth grader* "" OR "" seventh grader* "" OR "" eighth grader* "") OR ab("middle school student*") OR ab("preteen*" or "pre teen*") OR ab(teen*) OR ab(high school* student* or highschool* student*) OR ab(adolescent* or adolescence*) OR ab("college student*" or "university student*") OR ab("young adult*") OR ab("young person*" or "young people*" or "young women*" or "young men*") OR ab("secondary school" OR "secondary schooling" OR "secondary schools")) AND (ab("receptive language") OR ab("expressive language") OR ab("receptive vocabulary") OR ab("expressive vocabulary") OR ab(grammatical abilities) OR noft("language impairment") OR ab(grammatical judgement) OR noft("morphosyntax") OR MAINSUBJECT.EXPLODE("Language Acquisition") OR ab("verbal behavior") OR MAINSUBJECT.EXPLODE("Language Pathology") OR ab("language development") OR MAINSUBJECT.EXPLODE("Nonverbal Communication") OR noft("language tests") OR noft("verbal language") OR ab("verbal communication")) AND (ab(ASD) OR MAINSUBJECT("Autism") OR su(autis*) OR noft(Autism Spectrum Disorders))

ProQuest PsycINFO:

(ab("receptive language") OR ab("expressive language") OR ab("receptive vocabulary") OR ab("expressive vocabulary") OR ab(grammatical abilities) OR noft("language impairment") OR ab(grammatical judgement) OR noft("morphosyntax") OR MAINSUBJECT.EXACT("Language Development") OR ab("verbal behavior") OR MAINSUBJECT.EXACT("Language Disorders") OR ab("language development") OR MAINSUBJECT.EXACT("Nonverbal Communication") OR noft("language test*") OR noft("verbal language") OR MJMAINSUBJECT.EXACT("Verbal Communication")) AND (ab(asd) OR su(autis*) OR noft(Autism Spectrum Disorders)) AND (ab(child*) OR ab(preschool* or pre-school*) OR ab(school-age* or school age*) OR ab(toddler*) OR ab("school child*" or "schoolchild*") OR ab(youngster*) OR ab(juvenil*) OR ab(kids*) OR ab(youth*) OR (ab(kindergarten*) AND noft("" first grader* "" OR "" second grader* "" OR "" third grader* "" OR "" fourth grader* "" OR "" fifth grader* "" OR "" sixth

grader* "" OR "" seventh grader* "" OR "" eighth grader* "")) OR ab("middle school student*") OR ab("preteen*" or "pre teen*") OR ab(teen*) OR ab(high school* student* or highschool* student*) OR ab(adolescent* or adolescence*) OR ab(college student* or university student*) OR ab(young person* or young people* or young women* or young men*) OR ab(("secondary school" OR "secondary schooling" OR "secondary schools")) OR su(child*) OR su(young adult*) OR su("preschool") OR su(adolescent) OR ab(("primary school" OR "primary schooling" OR "primary schools")))

PubMed:

Search: ((((ASD[Title/Abstract]) OR (("autism spectrum disorder"[MeSH Terms] OR ("autism"[All Fields] AND "spectrum"[All Fields] AND "disorder"[All Fields]) OR "autism spectrum disorder"[All Fields]))) OR (autis* [text word])) AND ((((((((((((((("receptive language"[Text Word]) OR (expressive language [text word])) OR (receptive vocabulary[Text Word])) OR (expressive vocabulary [text word])) OR (grammatical abilities)) OR ("language impairment"[All Fields])) OR (grammat* judg*)) OR ("morphosyntax"[All Fields])) OR ("language development"[Title/Abstract])) OR (developmen* language disorder [text word])) OR ("Language Development Disorders"[Majr:NoExp])) OR ("Language Development"[Text Word])) OR ("Nonverbal communication"[All Fields])) OR ("Verbal Behavior"[All Fields])) OR ("Language Tests"[text word])) OR ("Language Disorders"[MeSH Terms])) OR ("verbal language" [text word]))) AND ((((((((((((((((((((((("college student*"[Title/Abstract]) OR ("university student*"[Title/Abstract])) (Child, Preschool[Mesh])) OR ("Child"[Mesh])) OR ("child*"[TIAB])) OR (preschool*[TIAB])) OR ("school-age"[Title/Abstract] OR "school age"[Title/Abstract])) OR ("kids"[TIAB])) OR ("schoolchild*"[TIAB] or "school child" [TIAB])) OR ("youth*"[TIAB])) OR ("kindergarten*"[TIAB])) OR ("juvenil*"[TIAB])) OR ("youngster*"[TIAB])) OR ("first grader*"[TIAB] or "second grader*"[TIAB] or "third grader*"[TIAB] or "fourth grader*"[TIAB] or "fifth grader*"[TIAB] or "sixth grader*"[TIAB] or "seventh grader*"[TIAB] or "eighth grader*"[TIAB])) OR ("middle school student*"[TIAB])) OR ("pre adolescen*"[TIAB] or "pre-adolescen*"[TIAB])) OR ("preteen*"[TIAB] or "pre teen*"[TIAB])) OR ("preadolescen*"[Title/Abstract] OR "pre adolescen*"[All Fields])) OR (secondary school*[TIAB])) OR ((highschool* or high school* [TIAB]))) OR (adolescent[MeSH Terms])) OR ("adolescent*"[TIAB] or adolescence* [TIAB])) OR ("teen*"[TIAB])) OR ("Young Adult"[Mesh])) OR ("young person*"[Title/Abstract] OR "young people*"[Title/Abstract] OR "young man"[Title/Abstract] OR "young woman"[Title/Abstract] OR "young men"[Title/Abstract] OR "young women"[Title/Abstract])) OR (("college student*"[Title/Abstract]) OR ("university student*"[Title/Abstract])))

Directory of Open Access Journals (DOAJ):

| | |
|---|---|
| autism and "receptive language" | social science; no SR |
| autism and "expressive language" | social science; no SR |
| autism and "receptive vocabulary" | social science; no SR |
| autism and "expressive | |

| | |
|---|---|
| vocabulary" | social science; no SR |
| autism and "grammatical abilities" | social science; no SR |
| autism and "language impairment" | social science; no SR |
| autism and "grammatical judgement" | social science; no SR |
| autism and "morphosyntax" | social science; no SR |
| autism and "language development" | social science; no SR |
| autism and "verbal behavior" | social science; no SR |
| autism and "language disorders" | social science; no SR |
| autism and "nonverbal communication" | social science; no SR |
| autism and "language test" | social science; no SR |
| autism and "verbal language" | social science; no SR |
| autism and "verbal communication" | social science; no SR |

# Supplementary Materials

**Supplementary Table 1**

*Diagnostic Information in Pre- and Post-DSM-5 Studies*

| Reference | DSM version | Diagnoses | Measures of Autism Traits |
|---|---|---|---|
| **DSM-5 studies** | | | |
| Bal et al. (2016) | not reported | ASD | ADOS- & ADI-R: not reported |
| Bal et al. (2020) | DSM-IV* | ASD: autism, PDD-NOS | ADOS: NR |
| Biller & Johnson (2020) | DSM-5 | ASD + "chromosomal abnormalities" | CARS & ADOS: not reported |
| Broome et al. (2022) | DSM-IV-TR/DSM-5 | ASD | None reported |
| Broome et al. (2021) | DSM-IV-TR/DSM-5 | ASD | None reported |
| Burton et al. (2020) | DSM-5 | ASD | ADOS-2: autism, ASD |
| Girolamo & Rice (2022) | DSM-5 | ASD | SRS-2 total *t*-score: 67 (8) |
| Girolamo et al. (2020) | not reported | educational diagnosis of autism | None reported |
| Haebig & Sterling (2017) | not reported | ASD, ASD+Fragile X syndrome | *ASD* \| *ASD+Fragile X syndrome*<br>ADOS: 7.7 (1.7) \| 7.6 (1.4) |
| Hart & Curtin (2021) | DSM-5 | ASD | ADOS-G, ADOS-T, ADOS, or ADOS-2: NR |
| Huang & Finestack (2020) | DSM-IV* | ASD: ASD, Asperger syndrome, PDD-NOS | CARS-2: 3 minimal, 9 mild to moderate, 3 severe |
| Jiménez et al. (2021) | DSM-5* | ASD | ADOS, ADOS-2, CARS, or ADI-R: not reported |
| Jokel et al. (2021) | DSM-IV/DSM-5 | ASD: ASD, Asperger syndrome, PDD-NOS | None reported |
| Jyotishi et al. (2017) | DSM-IV* | ASD: autistic disorder, PDD-NOS | ADOS: not reported |
| Klusek et al. (2014) | not reported | ASD, ASD+Fragile X syndrome | ADOS: not reported |
| Kover et al. (2014) | not reported | ASD | ADI-R & ADOS: 8 (1.6) |
| Nadig & Mulligan (2017) | not reported | ASD | ADOS: not reported |
| Nevill et al. (2017) | DSM-5 | ASD | ADOS-2: 8.1 (1.7)<br>ADOS-2 social affect: 8.1 (1.8)<br>ADOS-2 restricted and repetitive behaviors: 7.7 (1.5) |
| Plesa Skwerer et al. (2016) | not reported | autism, ASD | ADOS-2/A-ADOS total: 20.8 (5.2) |
| Reinhartsen et al. (2019) | not reported | ASD | ADI-R & ADOS social affect: 5.5 (1.4) |
| Sterling (2018) | not reported | ASD, ASD+Fragile X syndrome | *ASD* \| *ASD+Fragile X syndrome* ADOS/ADOS-2: 7.2 (2.2) \| 7 (1.7) |
| Thurman & Hoyos (2020) | not reported | ASD | ADOS-2: 6.8 (1.7) |
| **DSM-IV/DSM-IV-TR studies** | | | |
| Anderson et al. (2007) | DSM-IV | ASD, PDD-NOS | ADI-R & ADOS: not reported |
| Bennett et al. (2008) | DSM-IV | autism, Asperger syndrome | ADI: not reported |
| Bennett et al. (2014) | DSM-IV-TR | ASD | *ASD* \| *ASD+LI* \| *ASD+ID*<br>ADOS: 7.7 (1.7) \| 7.2 (1.4) \| 7.8 (1.7) |
| Botting & Conti Ramsden (2003) | DSM-IV | autistic disorder | CARS median: 34 |

| | | | |
|---|---|---|---|
| Charman et al. (2003) | DSM-IV | childhood autism, atypical autism, PDD-NOS | None reported |
| Condouris et al. (2003) | DSM-IV | autism | *ADI-R* \| *ADOS*<br>social interaction: 21.3 (5.1) \| 9.2 (2.1)<br>communication 17.5 (3.7) \| 5.5 (2.1)<br>repetitive behaviors/interests: 6.3 (2.6) \| not reported |

**Supplementary Table 1 (continued)**

| | | | |
|---|---|---|---|
| Eigsti & Bennetto (2009) | DSM-IV-TR | autistic disorder | ADI-R & ADOS: not reported |
| Eigsti et al. (2007) | DSM-IV | autism | *ADI-R* \| *ADOS*<br>communication: 15.3 (4.3) \| 6.8 (1.5) social reciprocity: 18.3 (4.9) \| 10.6 (2.7) repetitive behaviors/interests: 7.8 (2.4) \| 1.8 (1.3) |
| Ellawadi & Ellis Weismer (2015) | DSM-IV | autism | ADOS: 7.5 (1.9) |
| Ellis Weismer & Kover (2015) | DSM-IV-TR | ASD | ADOS: 7.6 (1.9) |
| Ellis Weismer et al. (2010) | DSM-IV* | autism, PDD-NOS | ADI-R & ADOS: not reported |
| Ellis Weismer et al. (2011) | DSM-IV* | ASD | ADI-R & ADOS: not reported |
| Gagnon et al. (2021) | DSM-IV | autism, PDD-NOS, Asperger Disorder | ADI-R & ADOS: not reported |
| Hartley et al. (2008) | DSM-IV-TR | autistic disorder, PDD-NOS | ADOS-G: autism, ASD (no Asperger syndrome) |
| Kjelgaard & Tager-Flusberg (2001) | DSM-IV | autistic disorder | ADI-R & ADOS-G |
| Kover & Ellis Weismer (2014) | DSM-IV-TR | ASD | ADI-R & ADOS: 7.2 (2) |
| Kover et al. (2013) | not reported | ASD | ADI-R & ADOS: 8 (1.6) |
| Landa & Goldberg (2005) | not reported | autism | ADI-R & ADOS/ADOS-G: not reported |
| Lindgren et al. (2009) | not reported | autism, ASD | ADI-R & ADOS-G |
| Luyster et al. (2007) | DSM-IV* | autism, PDD-NOS | ADI-R & ADOS |
| McGregor et al. (2012) | not reported | ASD | ASD \| ASD+LI ADOS: 13.2 (3.9) \| 15 (4.2) |
| Minshew et al. (1995) | DSM-III-R/DSM-IV | autistic disorder | ADI-R & ADOS: not reported |
| Modyanova et al. (2017) | DSM-IV | ASD | ADI-R & ADOS: not reported |
| Paul et al. (2008) | DSM-IV* | ASD: autism, PDD-NOS | ADOS communication: 3.3 (2.2) ADOS social interaction: 6.8 (2.1) |
| Perovic et al. (2013) | DSM-IV | ASD | ADI-R & ADOS: not reported |
| Prescott & Ellis Weismer (2022) | DSM-IV-TR | ASD | ADOS/ADOS-T: 7.6 (1.9) |
| Riley et al. (2019) | DSM-IV | autistic disorder, Asperger syndrome, PDD-NOS | ADOS-2: 6.7 (1.3) |
| Roberts et al. (2004) | DSM-IV | autism | ADI-R & ADOS: not reported |
| Thurm et al. (2007) | not reported | autism, PDD-NOS | ADI-R & ADOS: not reported |
| Thurm et al. (2015) | DSM-IV-TR | autism | ADOS: social affect: 6.8 (1.3)<br>ADOS restricted/repetitive behaviors: 8.3 (1.6) |
| Volden et al. (2011) | DSM-IV-TR | ASD | ADI-R & ADOS: not reported |
| Whitehouse et al. (2008) | DSM-IV | autism, ASD | ADOS-G; SCQ: 23 (6.7) |
| Worth & Reynolds (2008) | DSM-IV* | Asperger syndrome | DISCO: not reported |

| | | | |
|---|---|---|---|
| Woynaroski et al. (2016) **DSM-III-R studies** | DSM-IV-TR | ASD | ADOS: not reported |
| Rapin et al. (2009) | DSM-III-R | autistic disorder | WADIC: 8.2 (5.4) |

*Note.* ADI-R = Autism Diagnostic Interview-Revised (Lord et al., 1994). ADOS/-2/-G = Autism Diagnostic Observation Schedule/-2nd ed./Generic (DiLavore et al., 1995; Lord et al., 2000, 2012). CARS/CARS-2 = Childhood Autism Rating Scale (Schopler et al., 1980, 2010). DSM-III/III-R/IV/IV-TR/5 = Diagnostic and statistical manual of mental disorders-3rd/3rd-revised/4th/4th-text revision-5th edition (American Psychiatric Association, 1980, 1987, 1994, 2000, 2013). DISCO = Diagnostic Interview for Social and Communication Disorders (Wing et al., 2002). LI = language impairment. ID = intellectual disability. PDD-NOS = pervasive developmental disorder-not otherwise specified. SRS-2 = Social Responsiveness Scale-2nd Ed. (Constantino & Gruber, 2012). WADIC = Wing Autistic Disorder Interview (Wing 1985). * = study did not report but diagnosis could be confirmed through assessment of autism traits and diagnoses in original study.

**Supplementary Table 2**

*Language Criteria in Pre- and Post-DSM-5 Studies*

| Reference | Language Criteria |
|---|---|
| **DSM-5 studies** | |
| Bal et al. (2016) | **minimally verbal**: ADOS: Module 1; ADI-R item 30: no functional 3-word phrases used daily; Vineland Adaptive Behavior Scales-II expressive standard score ≤ 28; SCQ item 1: no phrases or sentences; and/or parent report: ≤ 25 words |
| Bal et al. (2020) | **language delayed**: ADOS Module 1 at age 3 **minimally verbal**: ADOS Module 1 at age 10.5 or 19 |
| Biller & Johnson (2020) | **minimally verbal**: ≤ 30 words |
| Broome et al. (2022) | - |
| Broome et al. (2021) | - |
| Burton et al. (2020) | **HFA**: full scale IQ ≥ 85, Vineland Adaptive Behavior Scales-II expressive language age ≥ 48 months |
| Girolamo & Rice (2022) | **LI**: -1.25 *SD* on ≥ 2: (a) Clinical Evaluation of Language Fundamentals-5th ed. core language, (b) Syllable Repetition Task, (c) Peabody Picture Vocabulary Test-5th ed., (c) Expressive Vocabulary Test-3rd ed., (d) Test of Early Grammatical Impairment composite |
| Girolamo et al. (2020) | - |
| Haebig & Sterling (2017) | - |
| Hart & Curtin (2021) | - |
| Huang & Finestack (2020) | **LI**: NVIQ ≥ 70 & Structured Photographic Expressive Language Test-3rd ed. standard score ≤ 95 |
| Jiménez et al. (2021) | **inclusion**: ≤ 250 words said (group matching) |
| Jokel et al. (2021) | - |
| Jyotishi et al. (2017) | **high-verbal**: Mullen Scales of Early Learning Expressive t-score ≥ -1 *SD* **mid-verbal**: Mullen Scales of Early Learning Expressive t-score ≤ -1 *SD* |
| Klusek et al. (2014) | **inclusion**: regular use of ≥3-word phrases |
| Nadig & Mulligan (2017) | - |
| Nevill et al. (2017) | - |
| Plesa Skwerer et al. (2016) | **minimally verbal**: < 30 spoken words/phrases or no phrase speech on a daily basis |
| Reinhartsen et al. (2019) | - |
| Sterling (2018) | - |
| Thurman & Hoyos (2020) | **inclusion**: NVIQ ≤ 110 (group matching) |
| **DSM-IV/DSM-IV-TR studies** | |
| Anderson et al. (2007) | - |
| Bennett et al. (2008) | **"HFA"**: spoke after 36 months, Test of Language Development-2nd ed. grammatical completion, grammatical understanding scaled score *M* ≤ -1.5 *SD* and NVIQ > 68 on Leiter/70 on Stanford-Binet **Asperger syndrome**: no significant early language delay |
| Bennett et al. (2014) | **Intellectual disability**: full scale IQ < 70 **LI**: full scale IQ > 70 & -1.5 *SD* on ≥1: Preschool Language Scales-4th ed. (PLS-4) Receptive Language, PLS-4 Expressive Language, Clinical Evaluation of Language Fundamentals-4th ed. Core Language |
| Botting & Conti Ramsden (2003) | **LI**: PIQ > 70, Expressive Vocabulary Test <10th percentile, Test for Reception of Grammar < 50th percentile |

| | |
|---|---|
| Charman et al. (2003) | - |
| Condouris et al. (2003) | **inclusion**: ability to complete language testing within age level |
| Eigsti & Bennetto (2009) | **"HFA"**: full scale IQ, verbal IQ & Peabody Picture Vocabulary Test-3rd ed. ≥ 85 **Supplementary** |

**Table 2 (continued)**

| | |
|---|---|
| Eigsti et al. (2007) | **inclusion**: produce ≥2 words & early LI |
| Ellawadi & Ellis Weismer (2015) | **prelinguistic**: Preschool Language Scales-4th ed. age equivalent of <15 months **first words:** Preschool Language Scales-4th ed. age equivalent of 15-23 months **word combinations**: Preschool Language Scales-4th ed. age equivalent of 24-35 months **sentences**: Preschool Language Scales-4th ed. age equivalent of >35 months |
| Ellis Weismer & Kover (2015) | **low language**: ADOS Module 1 & Preschool Language Scales-4th ed. total standard score ≤ 50 |
| Ellis Weismer et al. (2010) | - |
| Ellis Weismer et al. (2011) | - |
| Gagnon et al. (2021) | **inclusion**: mental age >18 months & no language regression, regression after first words, or regression after first phrases |
| Hartley et al. (2008) | **inclusion:** history of language delay |
| Kjelgaard & Tager-Flusberg (2001) | **borderline LI**: Peabody Picture Vocabulary Test-3rd ed. -1 to -2 SD **LI**: Peabody Picture Vocabulary Test-3rd ed. standard score ≤ -2 SD |
| Kover & Ellis Weismer (2014) | - |
| Kover et al. (2013) | - |
| Kover et al. (2014) | - |
| Lindgren et al. (2009) | **LI**: early language delay, Clinical Evaluation of Language Fundamentals-3rd ed. or Comprehensive Test of Phonological Processing Nonword Repetition Task < -1 *SD*, and VIQ > 50 |
| Luyster et al. (2007) | - |
| McGregor et al. (2012) | **LI**: Clinical Evaluation of Language Fundamentals-4th ed. Formulated Sentences & Recalling Sentences scaled scores < 8 |
| Minshew et al. (1995) | **"HFA"**: VIQ & FSIQ > 70, ≥ 2nd grade reading, spelling & arithmetic level |
| Modyanova et al. (2017) | **LI**: < 10th percentile on ≥2: (a) Peabody Picture Vocabulary Test-3rd ed., (b) Test for Reception of Grammar-2nd ed., (c) Kaufman Brief Intelligence Test vocabulary subtest |
| Paul et al. (2008) | **LI:** not reported |
| Perovic et al. (2013) | **LI**: < 10th percentile on ≥2: (a) Peabody Picture Vocabulary Test-3rd ed., (b) Test for Reception of Grammar-2nd ed., (c) Kaufman Brief Intelligence Test vocabulary subtest |
| Prescott & Ellis Weismer (2022) | word loss: ≥3 words any<br>communication skill loss<br>any word loss |
| Riley et al. (2019) | - |
| Roberts et al. (2004) | **borderline LI**: Test -1 to -2 *SD* on Peabody Picture Vocabulary **LI**: -2 *SD* on Peabody Picture Vocabulary Test |
| Thurm et al. (2007) | - |
| Thurm et al. (2015) | **minimally verbal:** no speech, single words & occasional phrases |
| Volden et al. (2011) | - |
| Landa & Goldberg (2005) | **"HFA"**: full scale IQ > 80 |

| | |
|---|---|
| Whitehouse et al. (2008) | **LI**: <10th percentile on ≥ 2: (a) Test for Reception of Grammar, (b) Expression, Reception, and Recall of Narrative Instrument Beach Story, (c) Test of Word Reading Efficiency sight word & phonemic decoding subtest, (d) Children's Communication Checklist-2nd ed, (e) NEPSY nonword repetition, (f) NEPSY memory for sentences |
| Worth & Reynolds (2008) | **"HFA"**: not reported |
| Woynaroski et al. (2016) | **minimally verbal**: Communicative Developmental Inventories words produced ≤ 20 & ≤ 5 different word roots on a 15minute language sample |
| **Supplementary Table 2 (continued)** | **DSM-III-R Studies** mixed receptive-expressive language disorders |
| | higher order language processing disorders |
| Rapin et al. (2009) | expressive phonology +/- grammar disorders |

*Note.* - = criteria not applicable. ADOS = Autism Diagnostic Observation Schedule (Lord et al., 2000). ADI-R = Autism Diagnostic Interview-Revised (Rutter et al., 2003). SCQ = Social Communication Questionnaire (Rutter et al., 2003a). Vineland Adaptive Behavior Scales-II (Sparrow et al., 2005). Clinical Evaluation of Language Fundamentals-3rd/4th/5th ed. (Semel et al., 1995, 2003; Wiig et al., 2013). Peabody Picture Vocabulary Test -3rd/5th ed. (Dunn, 2019; Dunn & Dunn, 1997). Expressive Vocabulary Test-3rd ed. (Williams, 1997, 2019). Test of Early Grammatical Impairment (Rice & Wexler, 2001). Syllable Repetition Task (Shriberg et al., 2009). Structured Photographic Expressive Language Test-3rd ed. (Dawson et al., 2003). Mullen Scales of Early Learning (Mullen, 1995). Test of Language Development-2nd ed. (Newcomer & Hammill, 1988). Leiter International Performance Scales-Revised (Roid & Miller, 1996). Stanford-Binet Intelligence Scales (Roid & Miller, 2012). Test for Reception of Grammar-2nd ed. (Bishop, 1982, 2003b). Comprehensive Test of Phonological Processing (Wagner et al., 1999).

**Supplementary Table 3**

*Cognitive Measures in Pre- and Post-DSM-5 Studies*

| Reference | IQ Assessment(s) | IQ Measure |
|---|---|---|
| **DSM-5 studies** | | |
| Bal et al. (2016) | Differential Abilities Scales-2nd ed. or Mullen Scales of Early Learning | **verbal mental age:** 1.4 (0.4)-2.8 (0.9)<br>**nonverbal mental age:** 3 (1)-4.5 (1.6) |
| Bal et al. (2020) | Mullen Scales of Early Learning or Merrill-Palmer-Revised | not reported |
| Biller & Johnson (2020) | Mullen Scales of Early Learning | **Visual Reception *t*-score**: 20 |
| Broome et al. (2022) | Stanford-Binet, Wechsler Intelligence Scale for Children-5th ed, Wechsler Preschool and Primary Scale of Intelligence-3rd ed., or Griffiths Mental Developmental Scales | **NVIQ** on Stanford-Binet (*n*=3): 88 (14.5)<br>**NVIQ** on WISC-V (*n* =1): 86<br>**NVIQ** on WPPSI-III (*n* =3): 99 (20.7)<br>**NVDQ** on Griffiths (*n* =13): 59.3 (23.4) |
| Broome et al. (2021) | Stanford-Binet, Wechsler Intelligence Scale for Children-5th ed, Wechsler Preschool and Primary Scale of Intelligence-3rd ed., or Griffiths Mental Developmental Scales | **NVIQ** on Stanford-Binet (*n*=3): 88 (14.5)<br>**NVIQ** on WISC-V (*n* =1): 86<br>**NVIQ** on WPPSI-III (*n* =3): 99 (20.7)<br>**NVDQ** on Griffiths (*n* =13): 59.3 (23.4) |
| Burton et al. (2020) | Kaufman Brief Intelligence Test-2nd ed. | **NVIQ, VIQ & FSIQ:** 107.2 (12.5)-111.8 (7.1) |
| Girolamo & Rice (2022) | Raven's Progressive Matrices-2nd ed. | **NVIQ:** 79.6 (15.3) |
| Girolamo et al. (2020) | Columbia Mental Maturity Scales | **raw score**: 36.4 (9.7), **maturity index**: 8.3 (1.5) |
| Haebig & Sterling (2017) | Leiter-Revised Brief | *ASD* \| *ASD+Fragile X syndrome*<br>**NVIQ**: 71.1 (20.8) \| 43.8 (7.2) |
| Hart & Curtin (2021) | | not reported |
| Huang & Finestack (2020) | Leiter-Revised Brief | **NVIQ:** 98.1 (20.2) |
| Jiménez et al. (2021) | Mullen Scales of Early Learning | none |
| Jokel et al. (2021) | Raven's Progressive Matrices | **NVIQ:** 56.7 (29.4) |
| Jyotishi et al. (2017) | Mullen Scales of Early Learning | *high-verbal* \| *mid-verbal*<br>**Visual Reception t-scores**: 59.1 (11.5) \| 37.7 (17.4)<br>**Fine motor t-scores**: 52.3 (18.6) \| 24.7 (6.7) |
| Klusek et al. (2014) | Leiter-Revised Brief | *ASD* \| *ASD+Fragile X syndrome*<br>**nonverbal mental age**: 6.7 (2) \| 5.1 (0.6) |
| Nadig & Mulligan (2017) | | none |
| Nevill et al. (2017) | Mullen Scales of Early Learning | **nonverbal age equivalent**: 20 months (5.4) |
| Plesa Skwerer et al. (2016) | Raven's Progressive Matrices | **NVIQ**: 62.7 (29) |
| Reinhartsen et al. (2019) | Mullen Scales of Early Learning | **Visual Reception age equivalent**: 43.4 months (16.9) |
| Sterling (2018) | Leiter-Revised Brief | *ASD* \| *ASD+Fragile X syndrome* **NVIQ**: 71.2 (19.9) \| 48.9 (8.1) |

| | | |
|---|---|---|
| Thurman & Hoyos (2020) | Differential Abilities Scales-2nd ed. | **NVIQ**: 76.1 (20.6) |
| **DSM-IV-TR studies** | | |
| Anderson et al. (2007) | | values not reported |
| **Supplementary Table 3 (continued)** | | |
| Bennett et al. (2008) | Leiter | **NVIQ**: 90.9 (17.5) |
| Bennett et al. (2014) | Merrill-Palmer Revised Scales of Development | age 3 *ASD* \| *ASD+LI* \| *ASD+intellectual disability*<br>**FSIQ**: 95.7 (15.6) \| 81.2 (8.2) \| 43.8 (16) |
| Botting & Conti Ramsden (2003) | | values not reported |
| Charman et al. (2003) | Leiter or Griffiths Mental Developmental Scales | **NVIQ**: 82.3 (25.1) |
| Condouris et al. (2003) | Differential Ability Scales | **NVIQ**: 90 (21)<br>**VIQ**: 83.7 (19.2)<br>**FSIQ**: 85.3 (19) |
| Eigsti & Bennetto (2009) | Wechsler Intelligence Scale for Children-3rd ed. or Wechsler Adult Intelligence Scales-3rd. ed. | **PIQ, VIQ & FSIQ**: 116 (20.1)-119 (14.1) |
| Eigsti et al. (2007) | Stanford-Binet 4 short form | **NVIQ**: 80 (15) |
| Ellawadi & Ellis Weismer (2015) | Bayley Infant Scales of Development-3rd ed. | **Cognitive**: 85.3 (10.6) |
| Ellis Weismer & Kover (2015) | Bayley Infant Scales of Development-3rd ed. | **Cognitive**: 84.8 (12.1) |
| Ellis Weismer et al. (2010) | Mullen Scales of Early Learning | **Nonverbal mental age**: 30.8 months (3.5) |
| Ellis Weismer et al. (2011) | Bayley Infant Scales of Development-2nd/3rd ed. | **Bayley II nonverbal cognition raw**: 3.5 of 11 (2.0)<br>**Bayley III cognitive:** 85.5 (10.8) |
| Gagnon et al. (2021) | Differential Ability Scales-2nd ed.,<br>Mullen Scales of Early Learning, Wechsler Adult Scale of Intelligence, or Wechsler Intelligence Scale for Children-4th ed. | **NVIQ**: 87.3 (23.4) **VIQ**: 82.3 (27.5) |
| Hartley et al. (2008) | Wechsler Intelligence Scale for Children-4th ed., Stanford-Binet-5th ed, Wechsler Preschool and Primary Scale of Intelligence-3rd. ed., or Wechsler Abbreviated Scale of Intelligence | **PIQ/NVIQ:** 86.9 (22.4) |

| | | |
|---|---|---|
| Kjelgaard & Tager-Flusberg (2001) | Differential Ability Scales | **NVIQ:** 83 (20.9)<br>**VIQ:** 76.3 (19.1)<br>**FSIQ:** 68.5 (24.4) |
| Kover & Ellis Weismer (2014) | Bayley Infant Scales of Development-3rd ed. or Mullen Scales of Early Learning | **Bayley Cognitive**: 87.2 (9.4)<br>**Mullen Visual Reception t-score**: 36.5 (12.3) |
| Kover et al. (2013) | Leiter-Revised Brief | **NVIQ:** 75.6 (19.9) |
| Kover et al. (2014) | Leiter-Revised Brief | **NVIQ:** 78 (19.5) |
| Lindgren et al. (2009) | Wechsler Intelligence Scales for Children-3rd ed. short form | *ASD* \| *ALI*<br>**NVIQ**: 109.4 (20.4) \| 91.3 (20.9)<br>**VIQ**: 113.5 (15.5) \| 85.1 (20.4)<br>**FSIQ**: 113 (16.5) \| 86.5 (19.2) |
| Luyster et al. (2007) | Differential Ability Scales or Mullen Scales of Early Learning | **NVIQ**: 61.7 (21.8) VIQ: 34.8 (22.9) |
| McGregor et al. (2012) | Kaufman Brief Intelligence Test-2nd ed. | *ASD* \| *ALI*<br>**NVIQ** 113 (12.3) \| ALI: 101 (12.1) |
| Minshew et al. (1995) | Wechsler Intelligence Scale for Children or Wechsler Adult Intelligence Scale-Revised | **PIQ, VIQ & FSIQ**: 93.2 (13.1)-94.1 (16.9) |
| Modyanova et al. (2017) | Kaufman Brief Intelligence Test | **NVIQ** ASD: 108.1 (17.8), ALI: 74.6 (22.9) |
| Paul et al. (2008) | Mullen Scales of Early Learning | **Visual Reception t-score**: 44.5 (17.1)<br>**Fine Motor t-score**: 35.7 (14) |

**Supplementary Table 3 (continued)**

| | | |
|---|---|---|
| Perovic et al. (2013) | Kaufman Brief Intelligence Test | *ASD* \| *ALI*<br>**NVIQ**: 108.2 (15.5) \| 66.9 (22.2) |
| Prescott & Ellis Weismer (2022) | Mullen Scales of Early Learning | **NV ratio IQ**: 76.7 (14.5) |
| Riley et al. (2019) | Mullen Scales of Early Learning | **Visual Reception age equivalent**: 25.6 months (10) **Fine Motor age equivalent**: 25.6 months (8.4) |
| Roberts et al. (2004) | Differential Ability Scales | *ASD* \| *ASD+borderline LI* \| *ASD+LI*<br>**NVIQ:** 95 (21) \| 79.6 (18.7) \| 71.3 (17)<br>**VIQ:** 92.1 (18.6) \| 74 (11) \| 60.3 (10.1)<br>**FSIQ:** 92.2 (18.8) \| 73.7 \| 62.5 (13.5) |
| Thurm et al. (2007) | Mullen Scales of Early Learning; or Differential Ability Scales | **NVIQ age equivalent ratio**: 0.6 (0.2)<br>*age equivalent to chronological age* |
| Thurm et al. (2015) | Mullen Scales of Early Learning | **NVDQ**: 64.6 (13.7), VDQ: 46.6 (14.3) |
| Volden et al. (2011) | Merrill-Palmer Revised | **NV mental age**: 25.3 months (11.9) |
| Landa & Goldberg (2005) | Wechsler Intelligence Scale for Children-Revised, Wechsler Intelligence Scale for Children-3rd ed., or Wechsler Adult Intelligence Scale-Revised | **PIQ, VIQ, and NFSIQ**: 104.6 (13.5)-113.5 (17.1) |
| Whitehouse et al. (2008) | Wechsler Abbreviated Scale of Intelligence | **NVIQ** ASD: 110.3 (14.9), ALI: 100.3 (11.7) |
| Worth & Reynolds (2008) | | none |

| | | |
|---|---|---|
| Woynaroski et al. (2016) | Mullen Scales of Early Learning | **overall mental age:** 12.1 months (4.7) |
| **DSM-III-R Studies** | | |
| Rapin et al. (2009) | Stanford-Binet | **NVIQ:** 95.5 (15.7), VIQ: 82.3 (15.8) |

*Note.* NVIQ = nonverbal IQ. NVDQ = nonverbal developmental quotient. VIQ = verbal IQ. FSIQ = full scale IQ. DAS/DAS-2 = Differential Ability Scales/DAS-2nd ed. (Elliott, 1990, 2007). Mullen Scales of Early Learning (Mullen, 1995). Merrill-Palmer Revised Scales of Development (Roid & Sampers, 2004). SB-4/5 = Stanford-Binet Intelligence Scales-4th/5th. Ed. (Roid, 2003; Thorndike et al., 1986). Wechsler Intelligence Scale for Children-5th ed. (Wechsler, 2014). Wechsler Preschool and Primary Scale of Intelligence-3rd ed. (Wechsler, 2002). Griffiths Mental Development Scale-Extended Revised (Luiz et al., 2006). Kaufman Brief Intelligence Scale/-2nd ed. (Kaufman & Kaufman, 1909, 2004). Raven's Progressive Matrices-2nd ed. (Raven et al., 1998, 2018). Columbia Mental Maturity Scale (Burgemeister et al., 1972). Leiter International Performance Scale-Revised (Roid & Miller, 1996). Bayley Scales of Infant Development-2nd/3rd ed. Cognitive Scale (Bayley, 1993, 2006).

**Supplementary Table 4**

*Language Domains Assessed and Language Measures in Pre- and Post-DSM-5 Studies*

| Reference | Domains | Scores |
|---|---|---|
| **DSM-5 Studies** | | |
| Bal et al. (2016) | **Overall Receptive:** Vineland/Vineland-II Receptive AE in months<br>Vineland/Vineland-II Expressive AE in months | 20.4 (9.6)-32.4 (19.2) **Overall Expressive**:<br>12 (4.8)-27.6 (6) |
| Bal et al. (2020) | **Overall Receptive:** Vineland/Vineland-II Receptive AE in months<br>Vineland/Vineland-II I Expressive AE in months | 14.1 (6.9) **Overall Expressive**:<br>12.7 (5.5) |
| Biller & Johnson (2020) | **Speech**: Voice Motor Production Assessment for Children global motor control, focal control | 90%, 54% |
| | **Overall Receptive**: Vineland-2 Expressive v-score, Mullen Receptive t-score | 15, 21 |
| | **Overall Expressive**: Vineland-2 Receptive, Mullen Expressive t-score | 8, 20 |
| | **Expressive Vocabulary**: Communicative Developmental Inventories words produced | 30 |
| Broome et al. (2021) | **Speech**: First Words First Sentences Test | not reported |
| | **Overall Receptive**: Preschool Language Scales-4 Auditory Comprehension | 66.1 (14.9) |
| | **Overall Expressive**: Preschool Language Scales-4 Expressive Communication | 65.6 (14.2) |
| | **Receptive Vocabulary**: Communicative Developmental Inventories # words understood | 232.8 (156.3) |
| | **Expressive Vocabulary**: Communicative Developmental Inventories # words produced | 169 (175.8) |
| Broome et al. (2022) | **Speech**: First Words First Sentences Test | not reported |
| | **Overall Receptive**: Preschool Language Scales-4 Auditory Comprehension | 72.7 (16.7) |
| | **Overall Expressive**: Preschool Language Scales-4 Expressive Communication | 71.3 (14.6) |
| | **Receptive Vocabulary**: Communicative Developmental Inventories # words understood | 276.6 (44.5) |
| | **Expressive Vocabulary**: Communicative Developmental Inventories # words produced | 209.9 (45.2) |
| Burton et al. (2020) | **Speech:** Children's Communication Checklist-2 Speech | 9.8 (2.5) |
| | **Overall Receptive:** Clinical Evaluation of Language Fundamentals-5 \| Vineland-II Receptive | 107.1 (12.1) \| 11.6 (2.9) |
| | **Overall Expressive:** Clinical Eval. of Language Fundamentals-5 \| Vineland-II Expressive | 10.1 (16.9) \| 11.7 (1.9) |
| | **Grammar:** Children's Communication Checklist-2 Syntax | 9.9 (1.8) |
| | **Semantics:** Children's Communication Checklist-2 Semantics | 8.1 (1.5) |

| | | |
|---|---|---|
| Girolamo & Rice (2022) | **Speech:** Test of Early Grammatical Impairment Phonological Probe | 100% |
| | **Overall Receptive:** Clinical Evaluation of Language Fundamentals-5 Receptive | 59.3 (11.6) |
| | **Overall Expressive:** Clinical Evaluation of Language Fundamentals-5 Expressive | 56.9 (15.2) |
| | **Receptive Vocabulary:** Peabody Picture Vocabulary Test-5 | 68.5 (15.1) |
| | **Expressive Vocabulary:** Expressive Vocabulary Test-3 | 71.8 (14.3) |
| | **Grammar:** Test of Early Grammatical Impairment expressive grammar, GJ A' composite | 74.1 (21.7), 0.7 (0.3) |
| Girolamo et al. (2020) | **Overall Receptive:** Clinical Evaluation of Language Fundamentals-3 Receptive | 52.8 (7.3) |
| | **Overall Expressive:** Clinical Evaluation of Language Fundamentals-3 Expressive | 53.7 (8.0) |
| | **Grammar:** Test of Early Grammatical Impairment elicited grammar composite | 83.8 (18.3) |
| | Test of Early Grammatical Impairment GJ A' GJ A' composite | 0.7 (0.3) |
| Haebig & Sterling (2017) | | *ASD* \| *ASD+Fragile X syndrome* |
| | **Receptive Vocabulary:** Peabody Picture Vocabulary Test-4 | 78.5 (21) \| 53.5 (17.7) |
| | **Expressive Vocabulary:** Expressive Vocabulary Test-2 | 81.1 (19.5) \| 54.6 (17) |
| Hart & Curtin (2021) | **Receptive Vocabulary:** Receptive One-Word Picture Vocabulary Test-4 | not reported **Expressive Vocabulary:** Expressive One-Word Picture Vocabulary Test-4, Communicative Developmental Inventories # words produced |
| Huang & Finestack (2020) | **Overall Receptive:** Test for Auditory Comprehension of Language-3 | 89.1 (19.2) **Grammar:** Structured Photographic Expressive Language Test-3 75.6 (13.8) |
| Jiménez et al. (2021) | **Expressive Vocabulary:** Communicative Developmental Inventories words produced **Supplementary** | 74.9 (75.7) |

**Table 4 (continued)**

| | | |
|---|---|---|
| Jokel et al. (2021) | **Overall Receptive:** Clinical Evaluation of Language Fundamentals-4 Receptive | 83 (23.8) |
| | **Overall Expressive:** Clinical Evaluation of Language Fundamentals-4 Expressive | 77 (23.2) |
| Jyotishi et al. (2017) | | *high-verbal* \| *mid-verbal* 59.9 (13.2) \| 30.8 (12.8) |
| | **Overall Receptive:** Mullen Receptive t-score | 58.9 (14.4) \| 25.6 (8.3) |
| | **Overall Expressive:** Mullen Expressive t-score | 224.3 (105.1) \| 42.5 (39.7) |
| | **Expressive Vocabulary:** Communicative Developmental Inventories # words produced | |
| Klusek et al. (2014) | | *ASD* \| *ASD+Fragile X syndrome* |
| | **Receptive Vocabulary:** Peabody Picture Vocabulary Test-3 AE in years **Expressive** | 6.1 (1.2) \| 5.5 (1.4) |
| | **Vocabulary:** Expressive Vocabulary Test AE in years | 6.1 (1.2) \| 5.5 (1.4) |
| Kover et al. (2014) | **Receptive Vocabulary:** Peabody Picture Vocabulary Test-4 **Receptive** | 71.2 (22.5) |
| | **Grammar:** Test for Reception of Grammar-2 | 66.7 (16.6) |
| Nadig & Mulligan (2017) | **Overall Receptive:** Mullen Receptive raw score | 39.3 (9.3) |
| | **Overall Expressive:** Mullen Expressive raw score | 36.4 (11.7) |
| Nevill et al. (2017) | **Overall Receptive:** Preschool Language Scales-5 \| Mullen \| Vineland-II Receptive AE | 12.8 (6.8) \| 10.1 (7.7) \| 11.7 (8.6) |
| | **Overall Expressive:** Preschool Language Scales-5 \| Mullen \| Vineland II Expressive AE | 11.3 (6) \| 12.7 (6.7) \| 12.4 (7.4) |
| Plesa Skwerer et al. (2016) | **Overall Receptive:** Vineland-II Receptive | 46.1 (10.8) |
| | **Receptive Vocabulary:** Peabody Picture Vocabulary Test-4 | 27.6 (15) |
| Reinhartsen et al. (2019) | **Overall Receptive:** Mullen Receptive AE in months **Overall** | 37.3 (17.9) |
| | **Expressive:** Mullen Expressive AE in months | 35 (16.2) |

| | | |
|---|---|---|
| Sterling (2018) | | *ASD* \| *ASD+Fragile X syndrome* |
| | **Speech:** Test of Early Grammatical Impairment Phonological Probe | 100% |
| | **Receptive Vocabulary:** Peabody Picture Vocabulary Test-4 | 74.4 (16.7) \| 63.7 (12.6) |
| | **Expressive Vocabulary:** Expressive Vocabulary Test-2 | 78.9 (17.9) \| 65.7 (10.4) |
| | **Grammar:** Test of Early Grammatical Impairment expressive grammar composite | 85.9 (20.3) \| 65.6 (28.6) |
| Thurman & Hoyos (2020) | **Overall Receptive-Expressive:** Differential Ability Scales-2 verbal | 69.9 (20.5) |
| **DSM-IV/DSM-IV-TR Studies** | **Receptive Vocabulary:** Peabody Picture Vocabulary Test-4 | 73 (23) |
| | **Expressive Vocabulary:** Expressive Vocabulary Test-2 | 73.3 (25.2) |
| Anderson et al. (2007) | **Overall**: Differential Ability Scales, Mullen, or Wechsler Intelligence Scales for Children-III | not reported |
| Bennett et al. (2008) | **Grammar:** TOLD-2 grammatical completion & grammatical understanding | 4.8 (2.3) |
| Bennett et al. (2014) | **Overall Receptive-Expressive:** Preschool Language Scales-4 /Clinical Evaluation of Language Fundamentals-4 total | *ASD* \| *ALI* \| *ASD+ID* 100.2 (20) \| 87.1 (13) \| 63.6 (18) |
| Botting & Conti Ramsden (2003) | **Overall Receptive-Expressive**: Clinical Evaluation of Language Fundamentals | not reported |
| | **Grammar:** Test for Reception of Grammar | 38 (5-50) |
| | **Expressive Vocabulary:** Expressive Vocabulary Test median percentile | 5 (0-16) |
| Charman et al. (2003) | **Receptive Vocabulary:** Communicative Developmental Inventories # words understood | 131 (108) |
| | **Expressive Vocabulary:** Communicative Developmental Inventories # words produced | 38.7 (68.7) |
| Condouris et al. (2003) | **Overall Receptive:** Clinical Evaluation of Language Fundamentals-Preschool/3 Receptive | 71.0 (20.4) |
| | **Overall Expressive:** Clinical Evaluation of Language Fundamentals-Preschool/3 Expressive | 74.6 (19.3) |
| | **Receptive Vocabulary:** Peabody Picture Vocabulary Test-III | 86 (19.2) |
| | **Expressive Vocabulary:** Expressive Vocabulary Test | 84 (17.6) |
| | **Grammar:** Clinical Evaluation of Language Fundamentals-Preschool/3 Word/Sentence Structure | 5.5 (3) |
| Eigsti & Bennetto (2009) | **Receptive Vocabulary:** Peabody Picture Vocabulary Test-III | 116.5 (10.5) Eigsti et al. (2007) **Receptive Vocabulary:** Peabody Picture Vocabulary Test-III AE in months 43.4 (14) |

**Supplementary Table 4 (continued)**

| | | |
|---|---|---|
| Ellawadi & Ellis Weismer (2015) | **Overall Receptive-Expressive**: Preschool Language Scales-4 | not reported |
| Ellis Weismer & Kover (2015) | **Overall Receptive:** Preschool Language Scales-4 Auditory Comprehension | 81.7 (26.5) |
| | **Overall Expressive:** Preschool Language Scales-4 Expressive Communication | 78.8 (25.9) |
| | **Receptive Vocabulary:** Peabody Picture Vocabulary Test-4 | 88.1 (22.1) |
| Ellis Weismer et al. (2010) | **Overall Receptive:** Mullen Receptive AE in months | 11.2 (7.3) |
| | Vineland-2 Receptive AE in months | 12.1 (6.9) |
| | **Overall Expressive:** Mullen Expressive AE in months | 12.9 (6.9) |
| | Vineland-2 Expressive AE in months | 10.0 (5.9) |
| Ellis Weismer et al. (2011) | **Expressive Vocabulary:** Communicative Developmental Inventories # words produced | 108.2 (76.1) |
| | **Expressive Grammar:** Communicative Developmental Inventories grammatical complexity | 19.0 (0-16) |
| Gagnon et al. (2021)* | **Overall Receptive-Expressive**: Vineland-II | not reported |
| | **Receptive Vocabulary:** Peabody Picture Vocabulary Test-4 | not reported |
| Hartley et al. (2008) | **Overall Receptive:** Oral and Written Language Scales Listening Comprehension **Overall** | 81.2 (20.7) |
| | **Expressive:** Oral and Written Language Scales Oral Expression | 83.1 (23.1) |

| | | |
|---|---|---|
| Kjelgaard & Tager-Flusberg (2001) | **Speech**: Goldman-Fristoe Test of Articulation | 90.2 (17.0) |
| | **Overall Receptive-Expressive**: Clinical Evaluation of Language Fundamentals-P/III total | 72.3 (17.7) |
| | **Receptive Vocabulary:** Peabody Picture Vocabulary Test-III | 70.4 (22.7) |
| | **Expressive Vocabulary:** Expressive Vocabulary Test | 69.0 (23.6) |
| Kover & Ellis Weismer (2014) | **Expressive Vocabulary:** Communicative Developmental Inventories words produced | 90.8 (79.8) |
| Kover et al. (2013) | **Receptive Vocabulary:** Peabody Picture Vocabulary Test-4 **Expressive** | 68.7 (23.4) |
| | **Vocabulary:** Expressive Vocabulary Test-2 | 71.3 (25.3) |
| Volden et al. (2011) | **Overall Receptive:** Preschool Language Scales-4 Auditory Comprehension | 67 |
| | **Overall Expressive:** Preschool Language Scales-4 Expressive Communication | 66 |
| Landa & Goldberg (2005) | **Grammar:** Clinical Evaluation of Language Fundamentals-Revised Formulated Sentences | 7.2 (2.7) |
| Lindgren et al. (2009) | | *ASD* \| *ALI* |
| | **Overall Receptive:** Clinical Evaluation of Language Fundamentals-III Receptive | 106.9 (15.1) \| 76.6 (18) |
| | **Overall Expressive:** Clinical Evaluation of Language Fundamentals-III Expressive | 105 (16) \| 72.5 (12.8) |
| | **Receptive Vocabulary:** Peabody Picture Vocabulary Test-III | 111.1 (11.9) \| 87.5 (17.4) |
| Luyster et al. (2007) | **Receptive Vocabulary:** Communicative Developmental Inventories # words understood | 116 (95.8) |
| | **Expressive Vocabulary:** Communicative Developmental Inventories # words produced | 51.7 (87.7) |
| McGregor et al. (2012) | | *ASD* \| *ALI* |
| | **Overall Receptive:** Clinical Evaluation of Language Fundamentals-4 Receptive | 111 (12.1) \| 83 (9.9) |
| | **Overall Expressive:** Clinical Evaluation of Language Fundamentals-4 Expressive | 108 (11.8) \| 69 (13.1) |
| | **Receptive Vocabulary:** Peabody Picture Vocabulary Test-III | not reported not reported |
| | **Expressive Vocabulary:** Expressive Vocabulary Test | |
| Minshew et al. (1995) | **Overall Receptive:** Detroit Test of Learning Aptitude-2 Oral Directions | 7.1 (3.6) |
| | **Overall Expressive:** Detroit Test of Learning Aptitude-2 Word Sequences | 8.4 (2.9) |
| Modyanova et al. (2017) | | *ASD* \| *ALI* |
| | **Expressive Vocabulary:** Kaufman Brief Intelligence Test Vocabulary | 108.8 (15.2) \| 71.5 (18.7) |
| | **Receptive Vocabulary:** Peabody Picture Vocabulary Test-III | 107 (15.8) \| 67.6 (16.6) |
| | **Grammar:** Test of Early Grammatical Impairment 3s+Past | 90.3 (22.2) \| 66.6 (34.6) |
| | Test for Reception of Grammar-2 | 97.4 (12) \| 60.1 (8) |
| Paul et al. (2008) | **Overall Receptive:** Mullen Expressive t-score \| Vineland Receptive AE in months | 41.1 (14.5) \| 37.7 (17.3) |
| | **Overall Expressive:** Mullen Receptive t-score \| Vineland Expressive AE in months | 44.4 (15.9) \| 33.6 (13.3) **Receptive-** |
| | **Expressive Vocabulary:** Communicative Developmental Inventories | not reported |

**Supplementary Table 4 (continued)**

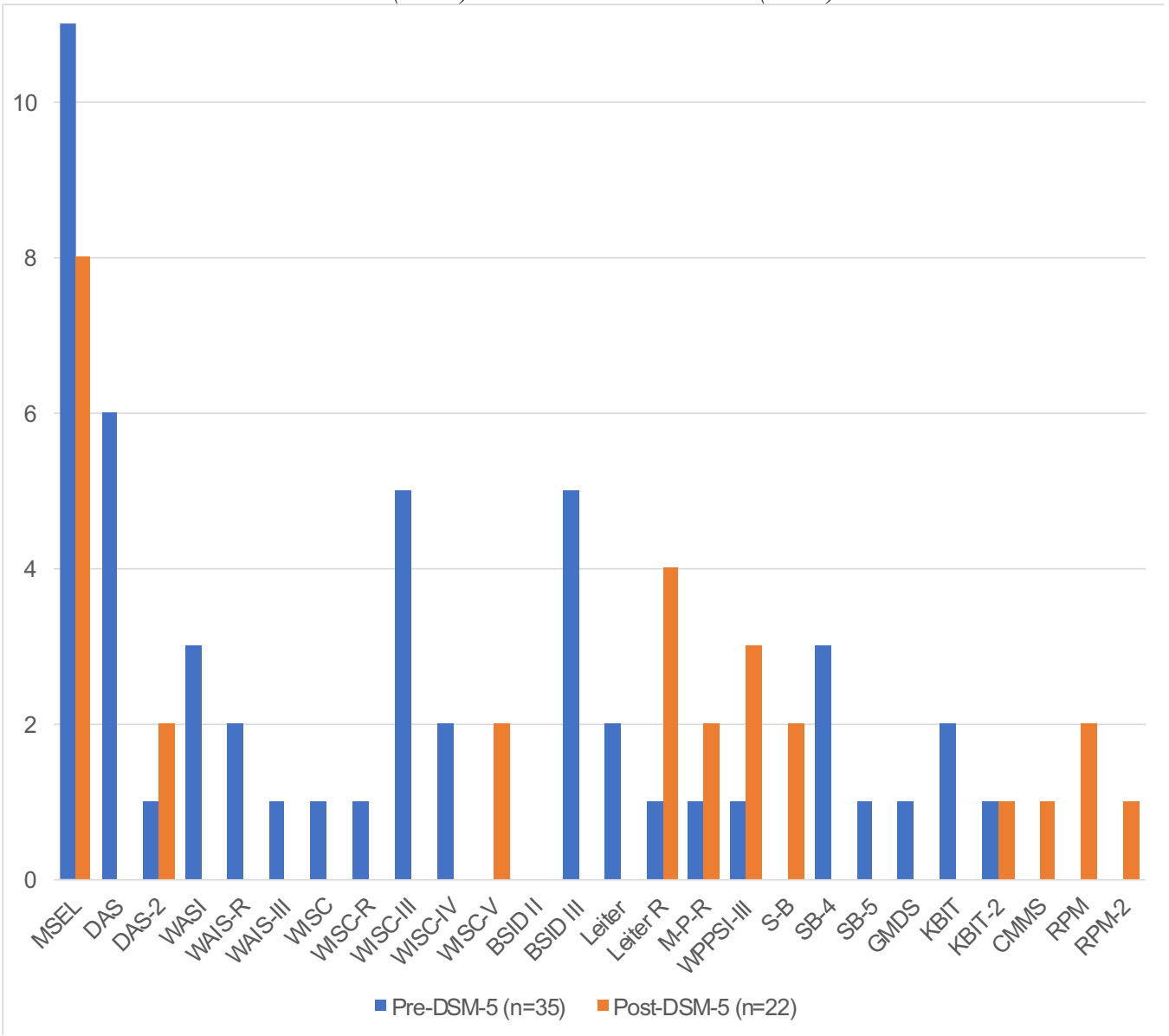
| | | |
|---|---|---|
| Perovic et al. (2013) | | *ASD* \| *ALI* |
| | **Receptive Vocabulary:** Peabody Picture Vocabulary Test-III | 111.9 (18.2) \| 58.5 (19) |
| | **Expressive Vocabulary:** Kaufman Brief Intelligence Test Vocabulary | 111.4 (17.8) \| 62.3 (20.5) |
| | **Receptive Grammar:** Test for Reception of Grammar-2 | 94.5 (12.3) \| 57.2 (4.7) Prescott & Ellis Weismer (2022) |
| **Overall Receptive-Expressive**: Preschool Language Scales-4 | | not reported |
| Riley et al. (2019) | **Overall Receptive:** Mullen \| Preschool Language Scales-5 Receptive AE | 19.4 (10.9) \| 20.8 (11.4) |
| | **Overall Expressive:** Mullen \| Preschool Language Scales-5 Expressive AE | 19.9 (10.6) \| 23.8 (10.7) |
| Roberts et al. (2004) | | *ASD* \| *BL* \| *ALI* |
| | **Speech**: Goldman-Fristoe Test of Articulation | not reported |
| | **Receptive Vocabulary:** Peabody Picture Vocabulary Test | 101.6 (17.1) \| 76.2 (5) \| 54.6 (8.9) |
| | **Grammar:** Test of Early Grammatical Impairment 3s probe | 76 (29) \| 61 (32) \| 37 (23) |

| | | |
|---|---|---|
| | Test of Early Grammatical Impairment Past probe | 64 (29) \| 58 (29) \| 31 (27) |
| Thurm et al. (2007) | **Expressive Vocabulary:** Differential Abilities Scale Naming Vocabulary AE ratio | 0.5 (0.3) |
| | **Overall Receptive:** Differential Abilities Scale Verbal Comprehension AE ratio | 0.4 (0.3) |
| Thurm et al. (2015) | **Overall Expressive:** Mullen Expressive AE | 18.9 (10.2) |
| Whitehouse et al. (2008) | | *ASD* \| *ALI* |
| | **Speech:** NEPSY oromotor sequences | 9.2 (1.8) \| 11.2 (2) |
| | **Narration:** Expression, Reception, and Recall of Narrative Instrument Beach Story | 93.8 (10.6) \| 86.3 (15) |
| | **Overall Receptive-Expressive:** Children's Communication Checklist-2 | *structural not reported* |
| | **Receptive Grammar:** Test for Reception of Grammar-Electronic | 101.8 (9.6) \| 85.3 (18.1) Worth & Reynolds (2008) |
| **Expressive Vocabulary:** | Assessment of Comprehension and Expression naming | 12 |
| | **Grammar:** Assessment of Comprehension and Expression syntactic formulation | 12 |
| | Assessment of Comprehension and Expression sentence comprehension | 11 |
| | **Semantics:** Assessment of Comprehension and Expression semantic decisions | 8 |
| Woynaroski et al. (2016) | **Overall Receptive:** Mullen Receptive AE in months 6.4 (6.2) **Overall Expressive:** Mullen Expressive AE in months 8 (4.2) | |
| | **Receptive Vocabulary:** Communicative Developmental Inventories # words understood | 115 (110) |
| | **Expressive Vocabulary:** Communicative Developmental Inventories # words produced | 18 (30) |
| **DSM-III-R Studies** | | |
| Rapin et al. (2009) | **Speech:** Photo Articulation Test | |
| | **Grammar:** Clinical Eval. of Language Fundamentals Sentence Structure/Semantic Relationships | 9.1 (1.1)<br>6.4 (4.7) |
| | **Receptive Vocabulary:** Peabody Picture Vocabulary Test | 75.7 (17.4) |
| | **Expressive Vocabulary:** Expressive One-Word Picture Vocabulary Test | 98.3 (19.7) |

*Note*. AE = age equivalent. AE ratio = age equivalent / chronological age. Preschool Language Scales-4th/5th ed. (Zimmerman et al., 2002, 2011). Differential Ability Scales/-2nd ed. (Elliott, 1990, 2007). Vineland Adaptive Behavior Scales-1st/2nd ed. (Sparrow et al., 1989, 2005, 2016). Voice Motor Production Assessment for Children (Hayden & Square, 1999). Mullen Scales of Early Learning (Mullen, 1995). Macarthur Communicative Developmental Inventories (Fenson et al., 2007). First Words First Sentences Test (Gillham et al., 1997). Children's Communication Checklist/-2nd ed. (Bishop, 1998, 2003a). Clinical Evaluation of Language Fundamentals-Revised/Preschool/3rd/4th/5th Ed. (Semel et al., 1987, 1995; Wiig et al., 1992, 2013). Peabody Picture Vocabulary Test-Revised/3rd/4th Ed. (Dunn & Dunn, 1981, 1997, 2007). Test for Reception of Grammar/TROG-2nd ed./TROG-electronic (Bishop, 1982, 2003b, 2005). Expressive Vocabulary Test-1st/2nd ed. (Williams, 1997, 2007). Oral and Written Language Scales (Carrow-Woolfolk, 1995). Photo Articulation Test (Pendergast et al., 1984). Test of Language Development (Newcomer & Hammill, 1988). Receptive One-Word Picture Vocabulary Test (Martin & Brownell, 2011b). Expressive One-Word Picture Vocabulary Test (Gardner, 1979). Test for Auditory Comprehension of Language-3rd Ed. (Carrow-Woolfolk, 1999). Structured Photographic Expressive Language Test-3rd ed. (Dawson et al., 2003). Wechsler Intelligence Scales for Children-3rd Ed. (Wechsler, 2002). Detroit Test of Learning Aptitude (Hammill, 1985). Assessment of Comprehension and Expression 6-11 (Adams et al., 2001). Goldman-Fristoe Test of Articulation (Goldman & Fristoe, 1986). Kaufman Brief Intelligence Scale/-2nd Ed. (Kaufman & Kaufman, 1990, 2004). Test of Early Grammatical Impairment (Rice & Wexler, 2001). Expression, Reception and Recall of Narrative Instrument (Bishop, 2004). NEPSY = A Developmental Neuropsychological Assessment (Korkman et al., 1998).

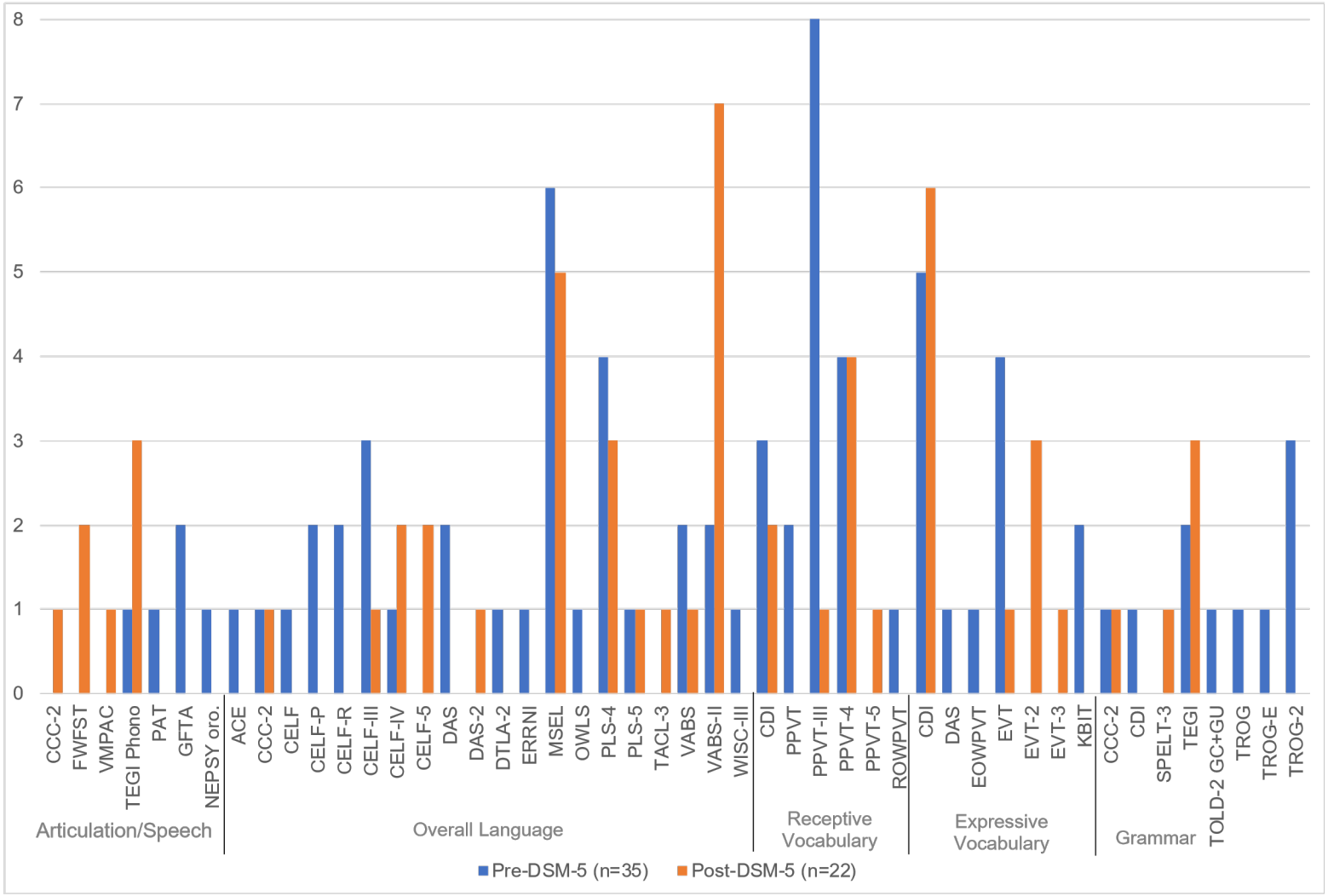
**Supplementary Figure 1**

*Count of IQ Assessments Used in Pre-DSM-5 Studies (n=35) and Post-DSM-5 Studies (n=22)*




**Supplementary Figure 2**

*Count of Age-Referenced Language Assessments Used in Pre-DSM-5 Studies (n=35) and Post-DSM-5 Studies (n=22)*



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