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Research Review: Language problems in children with Attention Deficit Hyperactivity Disorder – a systematic meta-analytic review

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Background: Children with ADHD appear to have a higher risk of language problems compared to typically developing children, although the types of language problems experienced are less clear. This review aims to establish the types of language problems experienced by children with ADHD according to systematically reviewed literature, and determine the empirical evidence for language problems in children with ADHD compared to non-ADHD controls. **Methods:** A standardized search protocol was used on databases: CINAHL, Medline, and PsychINFO. We identified studies with the following inclusion criteria: 1) confirmed ADHD status at the time of the study, 2) inclusion of a non-ADHD control group, 3) use of a validated language measure, and 4) *Age* ≤ 18. T-tests, Pearson's *r* and Hedges *g* effect sizes (ES) were calculated using summary statistics. Random effects meta-analyses were conducted for the language domain suitable for analysis. Publication bias was investigated using both the trim and fill and *p-curve* techniques. **Results:** Twenty-one studies were included in the systematic review (ADHD = 1209; Control = 1101), within which 60 of 68 separate analyses found significant differences between the ADHD and control group on the language measures ($p<.05$). Follow-up meta-analyses found evidence for large deficits in the ADHD groups overall (10/11 studies met $p<.05$; Weighted Mean ES [WMES]: 1.04); expressive (10/10 met $p<.05$; WMES: 1.23); receptive (12/14 met $p<.05$; WMES: 0.97) and pragmatic language (4/4 studies met $p<.05$; WMES: 0.98) compared to controls. **Conclusions**: This study demonstrates that children with ADHD have poorer performance on measures of overall, expressive, receptive and pragmatic language compared to controls. A screening of language functioning may be a valuable addition to the assessment of ADHD. **Keywords:** ADHD; language; attention; language disorder.

Introduction

There is growing evidence that children with Attention-Deficit/Hyperactivity Disorder (ADHD) have a higher prevalence of language difficulties than typically developing children. In one of the first population-based studies into comorbid language problems and ADHD, Beitchman and colleagues determined that five year-olds with language impairments had more than a six-fold risk of also having ADHD.[1] More recently, a community ascertained sample of children with ADHD were found to have a three-fold risk of also having comorbid language problems.[2]

However, much of the research examining language in children with ADHD has been subject to limitations that restrict firm interpretation of the overlap between conditions.[3] Predominately, studies comprise clinical samples which may over represent children with more severe ADHD and greater comorbid conditions. Issues also arise from inconsistent or inadequate methods of ADHD diagnosis and language assessment. For example, some studies have failed to include a gold-standard diagnostic assessment for ADHD, such as a diagnostic interview, or standardized rating scales; or have relied on unvalidated/unnormed measures for assessing language. While narrative reviews of language and ADHD have been published,[3-7] a systematic or meta-analytic review that considers such limitations has not yet been conducted. The true nature of language problems in children with ADHD is, therefore, unclear at this time.

There are various approaches to defining ‘language’ and its disorders, with no real consensus as to which approach should be followed.[8] A common framework distinguishes between language *modality* (i.e., comprehension/production; receptive/expressive) and *domains* of language structure (i.e., vocabulary, grammar, and discourse).[9,10] Put another way, modality refers to listening and speaking; while domain refers to the language units by which this is measured (i.e., words, sentences, and discourse).[11] Overarching this 2x3 matrix of modality x domain is pragmatics, which describes the contextually-appropriate use of social language.[12]

Issues surrounding how language should be conceptualized are illustrated in the Diagnostic and Statistical Manual of Mental Disorders (DSM), which has varied in its definition of communication disorders over time. For instance, the DSM-IV-TR differentiated between expressive and mixed receptive-expressive disorders, but did not include written language.[13] Conversely, the latest edition of the DSM-5 includes written language, but does not differentiate between receptive and expressive language. Finally, the DSM-5 only recently introduced a new category of social-pragmatic-communication disorder.[14]

In this paper, we use the term 'language problems' to describe a broad range of language difficulties, and distinguish between expressive, receptive and pragmatic language. We identify children with language problems via their performance on validated/standardised measures of language in comparison to a control group. Our approach captures the presence or absence of language difficulties, irrespective of etiological cause, as this is not well identified in the current literature. Finally, we restrict our focus to 'spoken language' measures, and do not include studies of written language or gesture - which are difficult to disentangle from motoric issues. Furthermore, the focus does not include reading disorders, as reading involves complex interaction and integration of visual graphical input, culturally defined semantic associations, comprehension and interpretation,[15] and is best left for separate systematic review in its own right.

The aim of this systematic and meta-analytic review was to 1) establish the types of language problems experienced by children with ADHD according to systematically reviewed literature, and 2) determine the empirical evidence for language problems in children with ADHD compared to non-ADHD controls.

Methods

Information sources

The review was completed in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[16] Databases CINAHL, PsychINFO and Medline were accessed using the EBSCOhost platform from the dates covering 1980 to December 2015. The search was limited to peer-reviewed publications presented in English. The search strategy utilized a combination of Medical Subject Headings (MeSH) terms for each database (provided in the Appendix S1, available online). Secondary references were also checked. Articles were screened by two independent raters. A standardized data collection protocol was employed to record the following information about each paper (see Table 1).

[Table 1]

Eligibility criteria

Eligibility criteria were as follows: 1) confirmation of ADHD status at the time of the study; 2) inclusion of a non-ADHD comparison group; 3) use of a validated measure of language function; and 4) participants ≤ 18 years of age. The review excluded samples of children with primary biological or neurological conditions that impact cognitive and language function directly (e.g., intellectual disorders, acquired brain injury).

Participants were required to meet symptoms or full diagnostic criteria for ADHD according to past or current versions of the Diagnostic Statistical Manual (DSM[14]) and/or the International Classification of Disease (ICD[17]). This could be assessed via a structured or semi-structured diagnostic interview, and/or through scoring above a threshold on a validated ADHD rating scale completed by informants in the home and school setting (usually a parent, and a teacher). A parent or teacher report that the child had been diagnosed with ADHD without any form of validation was insufficient for inclusion in the review. The assessment of language function was restricted to standardized/validated measures of key language modalities/domains (see Table 2 for a summary of inclusion and exclusion criteria). Language modalities/domains will henceforth be referred to as 'language domains'.

[Table 2]

Synthesis of results

Systematic Review

Data were analyzed using Stata 14. Two sample t-tests were conducted to compare the ADHD and non-ADHD control groups on language measures using the mean, *sd* and sample size; using a .05 alpha level and 95% confidence intervals. For the systematic review all relevant outcome measures were analyzed and Pearson's *r* (*r*) effect size was calculated for each (see Supplementary Material 2 for more information about these calculations). The study measures were categorized according to what aspect of language they assessed. The measures fell into four clear categories of those measuring the Overall, Expressive, Receptive and Pragmatic domains, and one 'other' category to capture measures that did not fall under the former domains.

Meta-Analyses

Data were analyzed using Stata 14 and Comprehensive Meta-Analysis[18] software. One meta-analysis was conducted for each of the suitable language domains. Studies in each domain had one main measure of the outcome variable (overall, expressive, receptive or pragmatic language respectively). To avoid double counting participants in studies which provided more than one measure of the same language domain, measures were either 1) averaged (mean and *sd*); 2) an overall score representative of the language domain in question were preferentially selected when available; or 3) the most common measure used across the studies was selected (see Supplementary Material 2). Hedges' *g* effect size[19] was calculated for each outcome measure. Pooling of study results within each language domain was conducted using an inverse variance-weighted method of random effects analysis, which also includes a measure of heterogeneity between studies into its calculation.[20] Homogeneity of effect size was further examined for each language domain by calculating the Q_t statistics.[21] The I^2 statistic and 95% confidence intervals were calculated[22] in order to assess the variability of effect size across studies within each domain (see Supplementary Material 2). Given that the 'other language' domain comprised different aspects of language functioning, the calculation of an overall effect size estimate was deemed not meaningful, and a meta-analysis was not conducted for this domain.

Publication bias

Publication bias was investigated using funnel plots and the Egger regression asymmetry test. Both the trim and fill technique[23] and p-curve [24,25] technique were used to quantify the presence of bias. The *p-curve* approach used data where unequal variance had cautiously been assumed (see Supplementary Material 2). A Robustness Test was also conducted for cases where there was ambiguity about the measure in question or multiple measures of the same language domain were provided within the same study (see Supplementary Material 2).

Results

Study characteristics

Figure 1 illustrates the flow of article collection. A total of 21 studies using 17 language measures were included in the systematic review (ADHD = 1209; Control = 1101; sample size range: 23-621; age range: 3-14 years, mode age: 7-11 years). Approximately 77% of the ADHD participants were male (*n*: 932). Comparing language function between children with and without ADHD was a specific aim in 17 (81%) of the studies. There was large variability in the language measures used. The most common measure was various versions of the Clinical Evaluation of Language Fundamentals (CELF; used in 10 studies[2,12,26-33]). All effect sizes were in a positive direction, meaning that children with ADHD had poorer performance than the control group on the respective language measures. All studies were cross-sectional in design. Fourteen studies used participants sampled from both clinical and community settings, 3 studies used samples sourced from clinical settings only,[34-36] and four from community settings only[2,12,37,38].

Within the systematic review there were 68 separate analyses conducted across the studies, of which eight found a non-significant difference between the ADHD and control group on the language measures ($p > .05$). One study did not provide relevant statistics and an effect size was incalculable.[39] In another study the odds ratio was used to calculate the effect size.[2] Three studies were not included in the subsequent meta-analysis as they did not provide appropriate statistics[39] or they included only measure for the 'other' language domain[40,41].

The results of the systematic review are outlined in Table 3. Ten studies, each with one outcome measure, were used to produce the Overall, Expressive and Receptive language domain meta-analyses respectively (see Supplementary Material 3 and

Figure 2). Four studies, each with one outcome measure, were used to produce the Pragmatic language domain meta-analysis (see Table 4 for meta-analyses results; see Figure 3 for Forest Plots).

[Table 3]

[Table 4]

[Figure 3]

Overall language

In the systematic review, children with ADHD had significantly poorer performance than controls on 11 of the 12 overall language measures ($p < 0.05$; *r range*: .30–.67). One study found no difference using the CELF-4 Screening Test ($p = .06$, *r:* .30).[33]

In the meta-analysis, one outcome measure from each of the 10 studies examining overall language produced a weighted mean effect size of 1.09 indicating a large relationship between ADHD and language problems on measures of overall language (*N*:830; Controls: 395, ADHD: 435; 76% of ADHD participants were male).

Egger's regression test indicated there was publication bias (*E*: 2.60; $p < .01$). Duval and Tweedie's trim and fill technique found one missing study. The adjusted values were marginally different from the observed values (*Adjusted Weighted Mean (g)*: 1.04, *95% CI*± .29; Q_t: 28.69; see Figure 4 for Funnel Plot). *P-curve* analysis required that one study be excluded from the model because $p > .05$.[33] The *p-curve* for the remaining nine studies ($p <.025$) was significantly right-skewed (Binomial test: $p = .002$; Continuous test full curve: *Z:* -9.94, $p < .0001$, and half curve *Z:*-9.01, $p < .0001$). Similarly, the Robustness Test's *p-curve* was also right-skewed (Binomial test: $p = .002$; Continuous test full curve: *Z:* -10.06, $p < .0001$, and half curve *Z:* -9.25, $p < .0001$) with all *p* values continuing to be $p < .025$. These results suggest that the body of studies reflects a true effect of overall language performance in ADHD children, and is not an artifact of publication bias and/or *p* hacking.

[Figure 4]

Expressive language

In the systematic review, children with ADHD had significantly poorer performance than controls on all 14 expressive language measures ($p < .05$; *r range*: .32–.87).

In the meta-analysis, one outcome measure from each of the 10 studies examining expressive language produced a weighted mean effect size of 1.23, indicating a very large relationship between ADHD and expressive language problems (*N*:653; Controls: 258, ADHD: 395; 82% of ADHD participants were male).

Egger's regression test indicated that there was publication bias (*E:* 5.64; $p < .01$), however, there were no missing studies found when the Duval and Tweedie trim and fill correction was applied. All studies were included in the *p-curve* analysis ($p <$ .025), which was significantly right-skewed (Binomial test: $p < .001$; Continuous test full curve: *Z:* -10.2, $p < .0001$, and half curve *Z:* -9.39, $p < .0001$). Similarly, the Robustness Test's *p-curve* was also right-skewed ($p < .001$), with all *p* values continuing to be $p < .025$. These results suggest that the body of studies reflects a true effect of expressive language performance in ADHD children.

Receptive language

In the systematic review, children with ADHD had significantly poorer performance than controls on 12 of the 14 measures of receptive language ($p < .05$; *r range*: .15–.65). One study found mixed results,[31] and a second did not find a significant group difference.[42] Specifically, Oram et al.[31] found a non-significant group difference on one receptive language subtest (linguistic concepts, CELF-R; $p = .08$, *r:* .39, $n = 19$), while all other subtests detected a significant difference between groups. Gut et al.[42] found no significant difference between children with ADHD and controls on the receptive language subtest of the Intelligence and Development Scale (IDS), however, there was a small effect size difference between groups (*N:*46; ADHD m[*sd*]: 8.7[3.21]; Control m(*sd*): 10.11[3.38]; *r*: .21 $p = .15$).[43] The study did not include participants with a history of a language disorder diagnosis from the initial sample recruitment. Finally, although significant, there was a small effect size difference between children with ADHD and controls in a large study using a Shorten Version of the Token Test (*N:*621; ADHD m[*sd*]: 30[4]; Control m[*sd*]: 31.2[3.7]; *r*: .15; $p <$ .01).[38]

In the meta-analysis, one outcome measure from each of the 10 studies examining receptive language produced a weighted mean effect size of .97, indicating a large relationship between ADHD and receptive language problem (*N*:1252; Controls: 622, ADHD: 630; 75% of ADHD participants were male).

Egger's regression test indicated that publication bias may be present in the analysis (*E*: 3.89; $p < .01$), however no adjustments were required. One study had to be excluded from the follow-up *p-curve* analysis due to $p > .05$.[42] The *p-curve* was significantly right-skewed (Binomial test: $p = .002$; Continuous test full curve: *Z:* -10.73, $p < .0001$, and half curve *Z:* -10.09, $p < .0001$). Similarly, the Robustness Test's *p-curve* was also right-skewed ($p < .001$), with all *p* values continuing to be p < .025. These results suggest that the body of studies reflects a true effect of receptive language performance in ADHD children.

Pragmatic language

In the systematic review, the CCC was a based on parent-report, while all other pragmatic measures directly assess language in the child (e.g., the Test of Pragmatic Language). This did not appear to affect the results, however, with all 8 measures of pragmatic language finding that children with ADHD had significantly poorer performance than controls ($p < .05$; *r range*: .27–.71).

In the meta-analysis, one outcome measure from each of the four studies examining pragmatic language produced a weighted mean effect size of .98 indicating a large relationship between ADHD and pragmatic language problems (*N*:315; Controls: 115, ADHD: 200; 88% of ADHD participants were male).

Egger's regression test did not indicate publication bias (*E*: .93, $p > .05$), but this does not preclude the possibility of publication bias given the very small number of studies in this meta-analysis. Regarding the *p-curve* analysis, all four studies used for this domain had $p < .025$ and the distribution of *p* values was significantly right-skewed (Binomial test: $p = .0625$; Continuous test full curve: *Z:* -8.1, $p < .0001$, and half curve *Z:* -6.48, $p < .0001$). Similarly, the Robustness Test's *p-curve* was also right-skewed (Binomial test: $p = .0625$; Continuous test full curve: *Z:* -8.36, $p < .0001$, and half curve *Z:* -7.73, $p < .0001$), with all four *p* values continuing to be lower than $p < .025$. Thus although there was only four studies used in this meta-analysis, there was sufficient evidence that the body of studies reflects a true effect of pragmatic language performance in ADHD.

Other language domain

The category of 'other language' measures captured additional findings in seven studies that met the inclusion criteria for this review, but did not fall under the domains mentioned above. These additional measures assessed narrative organization,[27,32] word retrieval,[31] phonological processing,[31,41] and semantic[34,36] and syntactic[36,40] elements of language, with largely mixed results.

For narrative organization skills, one study found significantly poorer language performance by children with ADHD on an overall measure of narrative abilities (p = .004; r: .51), narrative comprehension (p = .002; r: .38), and oral narration (p = .02; r: .48).[32] A second study found no difference between ADHD and control groups in their self-directed narration of a story when a sequence of pictures were provided to support the narrative (p = .41; r: .31), while a significant difference was observed when only one picture was provided (p = .01; r: .61).[27]

On semantic measures, the Test of Language Development (2nd Edition; [TOLD2]) found a significant difference between groups (p <.001; r: 31)[36], while the Language Processing Test (LPT) did not (p =.55; r: .12)[34].

On syntactic measures, one study found a significant difference between ADHD and controls on the syntactic subtest of the TOLD2 (p < .001; r: .43)[36]; while another study found no difference on morpho-syntactic language processing on the Illinois Test of Psycholinguistic Abilities (German Version; [Psycholinguisticher Entwicklungs Test; PET]; p = .20; r: .20)[40].

Regarding phonological processing, significant differences were found on measures of oral phonological awareness and phonological processing on the multiple levels of the Rosner Auditory Analysis Test ([RAAT]; p < .05).[31] Of note, the effect size (Pearson's r) difference increased as the phonological decoding requirements became more complex in the ascending levels of the RAAT measure (i.e., Level I r: .22; IV r: .33, V r: .37, VI r: .40, VII r: .42). However a second measure of phonological processing found no significant difference between groups (p = .10; r: .27).[41]

Only one study examined word retrieval skills, in which all subtests on the Test of Word Finding (TWF) showed a significant difference between ADHD and control groups (p < .05; r: .20–.32), except 'Picture Naming Verbs' (p = .79; r: .03).[31]

Meta-analysis could not be conducted on this domain due to lack of homogeneity in the outcome measures.

Discussion

We found that children with ADHD had poorer language functioning compared to controls, across the domains of Overall, Expressive, Receptive and Pragmatic language. Measures of language were generally based on a global language score across multiple subtests, typically including expressive and receptive subtests. The Pragmatic language domain had considerably fewer studies meeting inclusion requirements than all other domains, but nevertheless showed consistent findings of pragmatic language problems in children with ADHD.

Additional measures that did not fall within the Overall, Expressive, Receptive or Pragmatic domains were also assessed across the included studies (20 outcome measures). These 'other' measures can loosely be defined as those relating to language structure and form (i.e., the domain part of the modality/domain model described above). Results across these measures were somewhat inconsistent, however non-significant results tended to be associated with weaker effect sizes. Additionally, the limited number of studies that used measures involving varying levels of complexity also tended to show a pattern of larger deficits in ADHD children as the processing/narrative requirements became more demanding.[27,31]

A second purpose of this analysis was to determine the empirical evidence for language problems in children with ADHD compared to non-ADHD controls. There was large variability across the language measures used in this review. As such, only measures assessing the same domain of language were included in the respective meta-analyses, and studies could only contribute one measure to each meta-analysis. Meta-analyses revealed large mean effect sizes for all measured domains. The Expressive language domain had a very large weighted mean effect size (1.23); while Overall (1.04), Receptive (.97), and Pragmatic language (.98) domains had large weighted mean effect sizes (Hedges *g*). These effect sizes were adjusted to account for possible publication bias, and even once adjusted, the results continued to show a robust effect for each of the meta-analyses. Overall, the results of each meta-analysis provide strong evidence that ADHD is associated with weaknesses in several language modalities. Difficulties with expressive, receptive and pragmatic aspects of language should be considered a core component of the profile of ADHD deficits. Past literature has indicated that such language deficits are not currently being appropriately recognized or treated.[2]

Certain methodological issues need to be considered when interpreting the meta-analysis results. Firstly, the definition of 'language problems' has been made deliberately broad, and nonspecific to the nature of the language disorder, in order to maximize the inclusion of all relevant studies. Furthermore, given current controversy in the field,[44] restricting our focus to definitions like 'Specific Language Impairments' (SLI), for example, may have greatly restricted the findings. Given that only six of the 21 included studies also made comparisons between an ADHD and a comorbid

ADHD+language impaired group,[26-29,31,36] the results may suggest that language is impaired in ADHD children even in the absence of comorbid language disorders. While the results found that overall, children with ADHD score lower than their peers on standardized language tests, lower scores may not necessarily result from, or indicate the presence of, a language disorders per se.[8] Rather, such deficits may arise from problems in executive function[31] or working memory.[26] We make no etiological assumptions about the causes of language problems in children with ADHD given the lack of research in this area, which requires further investigation. Thus the question remains as to whether the meta-analyses results truly reflect problems with language function specifically, or are better explained by more global developmental problems. To some degree, global development problems can be overcome by the inclusion of minimum intellectual quotient (IQ) requirements in sample recruitment. Indeed, the majority of studies included in this review required an IQ score of at least 80 or more, and no study included participants with an IQ below 70.

Moreover, the focus on standardized tests –while sensible for the meta-analysis – omits numerous studies that have used other systematic approaches for studying discourse and conversational skills in children with ADHD (i.e., involving extended stretches of spoken language).[45,46] These studies typically find marked language impairments in children with ADHD which continue into adulthood and persist even when the formal diagnosis of a language disorder is no longer met.[47,48] Given the exclusion of such tests, it is likely that the present review may be underestimating the degree of language difficulties in children with ADHD.

Another limitation was the aggregation of findings across studies from clinically and community drawn samples. The effect of combining such samples together to create one overall mean effect size could be both the upwards 'pull' of clinical studies with highly symptomatic ADHD children, or the reverse from less symptomatic community-based studies. In this review, the majority of studies used a sample obtained from both clinical and community sources. ADHD symptomatology is known to be more severe and have a greater frequency of comorbid conditions in clinical populations, and this has limited of the generalizability of a large amount of ADHD research in the wider literature.[3] Nevertheless, the four included studies which exclusively examined community ascertained samples consistently found evidence of poorer language function in ADHD groups,[12,37,38] even in studies which covaried for the presence of internalizing and externalizing comorbidities.[2] Thus the findings cannot be purely explained by severe clinical samples alone.

While language problems are not included as a core diagnostic criteria of ADHD in current clinical classification systems (e.g. DSM, ICD), they are a common feature of its presentation in terms of both linguistic and pragmatic deficits.[49] Theoretical models attempting to account for the language deficit have postulated that it may simply be an expression of the ADHD symptoms, which have a secondary effect on language performance.[3,50] For example, language problems may be secondary to already present deficits in learning and concentration due to ADHD alone.[2] Other factors commonly associated with ADHD could also account for this comorbidity, such as poor socioeconomic status (SES)[51] and/or the increased prevalence of learning disorders,[52,53] both of which are known to have secondary a impact on language skills.[54] The potential cyclical nature of these factors has been demonstrated by findings that indicate language abilities in infancy and early childhood predict school readiness and later academic achievement;[54,55] as well as findings that SES relates to differences in exposure to words[56] and selective attention skills[54] which in turn effect language abilities. Alternatively, the language deficits may be a unique contribution of the ADHD profile, which occurs irrespective of secondary influences. Recent research suggests that within a diagnostically confirmed ADHD group, ADHD status was the only unique predictor of comorbid language problems, with no other comorbidity or socio-economic status factors independently contributing to their presence.[2] Finally, neurodevelopmental explanation could account for this association. Multiple aberrations in the brains of children with ADHD have been documented (see Konrad[57] for a comprehensive review), some of which may account for problematic language skills. For instance, preliminary neuroimaging studies have found that children with ADHD have smaller bilateral cerebral volume, which is associated with receptive language difficulties;[58] atypical pars triangularis, which is related to expressive language function;[59] and atypical right hemisphere brain morphology which is associated with poorer social comprehension.[60] However, a comprehensive neuroimaging analysis of the language networks in children with ADHD is yet to be undertaken.

Early identification of language difficulties and possible interventions for this vulnerable group may improve functional outcomes over the long-term. Recently, less than half of children with ADHD and comorbid language problems were found to have ever accessed speech pathology services, and only one-quarter of these children were currently receiving language services.[2] Thus, while there has been increasing acknowledgement of the language problems that often accompany ADHD, this does not appear to have translated to the implementation of consistent language screens or appropriate language interventions for children with ADHD. Given the increased prevalence of language difficulties in children with ADHD, implementation of at least a screen for language problems in clinical practice may assist with their identification in this patient group. As noted above, very few studies have investigated the language problems experienced by children with ADHD using neuroimaging measures, and this would seem to be the next logical step of the investigation. If aberrations in the language networks of children with ADHD were identified, this would support interventions that develop speech-language skills or compensatory language strategies.[61] Alternatively, if the root of the language issues seen in ADHD are secondary to attention based deficits (such as executive or working memory deficits for example) a more appropriate treatment intervention may involve tackling attention skills at a young age as these translate to poorer learning and language in later life. To this end, Neville et al. (2013) implemented an intervention that focused on developing better attention spans in preschool children with lower SES, and found that this related to improved selective attention and receptive language skills, as well as improved behaviour as reported by the parent.[54] Clarity on the root cause of such deficits is particularly important given its potential to tailor more cost-effective treatment interventions for this costly disorder. [62,63]

In summary, the review provides evidence that children with ADHD experience large deficits in their language functioning across expressive, receptive and pragmatic language modalities, culminating in overall language problems. Furthermore, results suggest that children with ADHD may require assessment on both simple and more complex measures of language structure and form in order to avoid missing more subtle deficits. This analysis is the first of its kind to systematically consolidate the literature investigating language performance in ADHD children according to rigorous diagnostic and language measures. This review supports the need for thorough evaluation of language function in children presenting with ADHD. As a minimum, we recommend a brief language screen be included in the routine assessment of children with ADHD so that potential language deficits can be appropriately followed-up and treated.

Supporting Information

Additional Supporting Information may be found on the online version of this article.

Appendix S1: Database search terms

Appendix S2: P curve disclosure Table

Appendix S3: MOOSE checklist

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Table 1. Data Extraction Items.

Data Category	Description	Data Extraction
1	Study description	Aim: Focus on language problems and ADHD (Y/N), design, sampling recruitment type, age, sex, accepted/excluded comorbidity, medication status, sample size, *n* of sex and subtypes/participant groups, IQ cut off.
2	ADHD diagnosis	Language the interview was conducted in, diagnostic criteria, interview (structured/semi/schedule), qualifications of assessor, parent/teacher input via

		scale/questionnaire/interview), cut-off score, child input (interview).
3	Language measure	Name of instrument(s), description of language domain assessed, number of items, language version, assessment of validity of measure.
4	Results	Language results (m[*sd*]), *p* value and effect size (where provided by researcher), nature of language deficit.
5	Study quality	Valid measures of diagnosis and outcome variables, sample size and effect size (Cohen's d and Pearson's r; calculated by HK).

Table 2. Summary of Inclusion and Exclusion Criteria.

Variable	Included	Excluded
ADHD	Diagnosis confirmed at the time of the study; DSM/ICD defined criteria; Above threshold using validated ADHD rating scales.	Diagnosis not confirmed at the time of the study; based on past diagnosis of ADHD only; diagnosis based on unstandardized measure; diagnosis based parent or teach report only without validation.
Comorbidities	Externalizing disorder/s; internalizing disorder/s; ASD.	Traumatic Brain Injury; primary neurological disorder.
Language	All language domains assessed; validated/standardized measure; direct measure of language or validated informant rating scale.	Non-validated/non-standardized measure; measures of non-language domain (e.g., reading, speech, writing abilities, executive function, memory).
Sample	N > 1.	Case studies.
Gender	Male only; female only;	Nil

	mixed samples.	
Age	≤ 18 years of age.	≥19 years of age.
Control	Comparison to a control group.	No control group comparison.
Medication	Any ADHD medication; on or off medication.	Nil.
Study focus	Studies that include language measures and appropriate sample groups	Neuroimaging; Genetic studies; participant recruitment given exposure to extraneous environmental factors (e.g. prenatal tobacco or drug use, exposure to lead).
Type	Published; original data*; peer reviewed; publication in English.	Unpublished; dissertation; non-peer reviewed.

* Where a series of studies were published using the same sample, only one study could be chosen to avoid sample 'double dipping'.

Table 3. Systematic Review of Difference Between ADHD & Control Groups on Language Measures.

Study	Relevant Exclusions[a]	IQ Cut-off or Means	Age	N[b]	Domain	Measure	ES[c]
Berry et al. (1985)		FSIQ 95-102	7-13	228	Overall: Language subtest	YCI**	N/A[e]
Cadesky et al. (2000)		VIQ and PIQ <80	7-13	113	Pragmatic Non-verbal social processing	DANVA**	.27
Geurts et al. (2004)	Nil Females & ADHD med[d]	FSIQ <80	6-13	95	Pragmatic skills	CCC; Parent**; Teacher*	.71; .51
Gut et al. (2012)	Language disorders	IQ <85	6-10	46	Overall: Language Composite Score	IDS**	.38
					Receptive	IDS; Receptive subtest	.21
					Expressive	IDS; Expressive subtest**	.47
Hutchinson et al. (2012)	Nil ADHD med	Non-verbal IQ ≤85	6-9	51	Receptive	CELF-4; RLI**	.57
					Expressive	CELF-4; ELI**	.57
Jonsdottir et al. (2005)		Non-verbal IQ <85	8-13	62	Overall: Spoken Language Quotient	TOLD2**	.52
					Receptive	TOLD2**	.51
					Expressive	TOLD2**	.49
					Other: Semantic	TOLD2**	.56
					Other: Syntactic	TOLD2**	.43
Luo & Timler (2008)		<80 FSIQ	8-12	25	Overall: Core Language Score	CELF-4**	.67
					Other: Narrative language	TNL; Picture sequence	.31
						TNL; Single picture*	.61
Martinussen & Tannock (2006)	Nil ADHD med	<80 FSIQ;	7-13	128	Expressive	CELF-III; RS**	.40
					Receptive	CELF-III; C&D**	.54

McInnes et al. (2003)	Nil females & ADHD med	Block Design WISC-III mean scaled score 90-93	9-12	58	Expressive	CELF 3; ELI**	.67
					Receptive	CELF 3; RLI**	.65
					Receptive	PPVT-III**	.52
					Expressive vocabulary & word retrieval	EVT**	.58
Oram Cardy et al. (2010)	Nil ADHD med	<80 PIQ on WISC-III	6-11	49	Overall: Core Language Score	CELF-3**	.53
					Receptive	CELF-3; RLI**	.55
					Expressive	CELF-3; ELI**	.42
Oram, et al. (1999)[f]	Nil ADHD med	<80 FSIQ	7-11	77	Overall: Core Language Score	CELF-R **	.58
					Receptive	CELF-R; RLI subtests*	.25-47
						RLI subtests LC	.39
					Expressive	CELF-R; ELI subtests **	.36-.78
					Other: Word Retrieval Skills	TWF subtests*	.20-.32
						TWF subtest PNV	.03
					Other: Oral Phonological awareness/phonological processing	RAAT levels III-VII*	.22-.42
Pineda et al. (2007)	Nil ADHD med	FSIQ <85	6-11	621	Receptive	Token Test (Short)**	.15
Purvis & Tannock (1997)[f]	Nil females & ADHD med	FSIQ <80	7-11	23	Expressive vocabulary/semantics	TWT **	.87
				28	Other: Semantic language	LPT	.12
Redmond & Ash (2014)	Comorbid LI	Non-verbal IQ <80 (NNAT)	7-8	40	Overall: Verbal Language	CELF-4 Screening test Total Score	.30
Redmond (2004)	Comorbid LI	Non-verbal IQ mean between 99-107	5-8	23	Overall: Spoken Language Quotient	TOLDP3**	.59

Sciberras et al. (2014)		Matrix reasoning WAIS scaled score mean 94	6-8	390	Overall: Oral Language – Criterion Score	CELF 4 Screener**	.39
Staikova et al. (2013)[f]	Nil ADHD med	FSIQ <80	7-11	63	Receptive	CELF-4; C&FD**	.39
				62	Expressive	CELF-4; FS**	.32
				63	Pragmatic	CASL Subtests*	.30-.48
						TPOL2*	.27
Tiffin-Richards et al. (2008)	Nil ADHD med	IQ < 80	10-14	39	Other: Morpho-syntactic language processing; psycholinguistics	PET	.20
Timler (2014)		IQ: 82-130	5-8	44	Overall: Communication skills;	CCC-2; GCC **	.47
					Overall: Core Language Score	CELF-4**	.36
					Pragmatic	CCC-2; PC**	.47
					Other: Narrative organizational skills	TNL; NLAI **	.51
						TNL; NC**, ON *	.38, .48
Van De Voorde et al. (2010)	Nil ADHD med	FSIQ <80	8-12	38	Other: Phonological processing	Dyslexia Screening Test**	.27
Yochman et al. (2006)		WPSSI VIQ mean 102-110	3-6	97	Overall: Verbal subscale	MAP**	.53
					Receptive	RDL Scale; Comprehension subtest**	.31

[a] – Where one gender, a language comorbidity, medication use was excluded; [b]- N (sample size) on which the analysis was based; [c]- ES (Effect Size); Pearson's *r;* [d]- 'Nil ADHD med' means that at the time of testing children had to stop their ADHD medication but were allowed to have a history of medication use. [e]- Not able to calculate ES for this study due to lack of statistical information. [f] - Varying sample sizes reported due to missing data between measures as reported by Oram et al. (1999, p. 76), Purvis & Tannock (1997; p. 140), Staikova et al. (2013; p. 1277). Note that the higher sample size estimate for these studies was use to calculate overall participant numbers for the systematic review. *Nb*. Significance: <.01**, <.05*

ADHD – Attention Deficit Hyperactivity Disorder; ASD - Autism Spectrum Disorder; CASL- Comprehensive Assessment of Spoken Language [and its subtests IN – Inferences, NL Nonliteral Language, PJ - Pragmatic Judgment]. CCC - Child Communication Checklist [and its subtests: GCC- General Communication Composite, PR - Parent Rated, PC- Pragmatic Composite, TR - Teacher Rated]. CELF- Clinical Evaluation of Language Fundamentals [and its subtests: CLS- Core Language Score, ELI – Expressive Language Index, FS - Formulated Sentence, LC- Linguistic Concepts, LP - Listening to Paragraphs, OD - Oral Directions, RLI - Receptive Language Index, RS – Recalling Sentences, SA- Sentence Assembly, WC - Word Classes, WS - Word Structure, C&FD - Concepts and Following Directions]. DANVA - Diagnostic Analysis of Nonverbal Accuracy; DBD- Disruptive Behaviour Disorder; EVT- Expressive Vocabulary Test; FSIQ: Full scale IQ; IDS - The Intelligence and Development Scale; IQ – Intelligence Quotient; LI – Language Impairment; LPT - Language Processing Test; MAP- Millers Assessment for Preschoolers; PDD – Pervasive Developmental Disorder; PET - Psycholinguisticher Entwicklungs Test; PIQ; Performance Intelligence Quotient; PPVT- Peabody Picture Vocabulary test- III; RAAT - Rosner's Auditory Analysis Test; RDL - Reynell Developmental Language; TNL - Test of Narrative Language [and its subtests: GAO- Goal Attempt Outcome, NC - Narrative Comprehension, NLAI - Narrative Language Ability Index, NNAT- Naglieri Nonverbal Abilities Test-Individual Administration; ON - Oral Narration, Seq - Picture Sequence, Sin - Single Picture]. TOLD2 - Test of Language Development 2, Intermediate, Icelandic Version; TPOL2 - Test of Pragmatic Language, 2nd ed [and its subtests: Sem – Semantic, Syn – Syntactic]. TD- Tic Disorders; TWF - Test of Word Finding [and its subtests: Description Naming, Picture Naming Categories, Picture Naming Nouns, Sentence Completion Naming, and PNV - Picture Naming Verbs]. TWT- The Word Test; WAIS – Wechsler Abbreviated Scale of Intelligence; WISC – Wechsler Intelligence Scales for Children [and its indices PIQ – Performance IQ]; WPPSI – Wechsler Preschool and Primary Scale of Intelligence [and its indices VIQ- Verbal IQ]; YCI - Yale Children’s Inventory; VIQ: Verbal Intelligence Quotient.

Table 4. Meta-Analyses of Differences in Language Function between Children with and without ADHD using Random Effect Models.

Study	ADHD Criteria[b]	Control/ ADHD (n)	Effect size (g) of the Difference between Groups[a] Overall	Expressive	Receptive	Pragmatic
Cadesky et al. (2000)	IV	27/86	-	-	-	.65
Geurts et al. (2004)	IV/ICD-10	41/54	-	-	-	1.61
Gut et al. (2012)	ICD-10	23/23	.81	1.03	.42[NS]	-
Hutchinson et al. (2012)	IV-TR	24/27	-	1.42	1.37	-
Jonsdottir et al. (2005)	IV	15/47	1.42	1.31	1.38	-
Luo & Timler (2008)	IV	13/12	1.73	-	-	-
Martinussen & Tannock (2006)	IV	34/94	-	.98	1.46	-
McInnes et al. (2003)	IV	19/39	-	1.85	1.26	-
Oram Cardy et al. (2010)	IV	28/21	1.23	.93	1.32	-
Oram et al. (1999)	IV	24/53	1.51	1.46	.93	-
Pineda et al. (2007)	IV	372/249	-	-	.31	-
Purvis & Tannock (1997)	III	9/14	-	3.41	-	-
Redmond & Ash (2014)	IV	20/20	.61[NS]	-	-	-
Redmond (2004)	IV	13/10	1.42	-	-	-
Sciberras et al. (2014)	IV	212/178	.56	-	-	-
Staikova et al. (2013)[c]	IV-TR	35/28	-	.68[c]	.85	.56
Timler (2014)	IV-TR	12/32	.84	-	-	1.11
Yochman et al. (2006)	IV	48/49	1.27	.68	.65	-
		Hedges G Weighted Mean Effect Size	1.09	1.23	.97	.98
		± 95% confidence interval	.30	.32	.34	.51
		Number of studies that showed a significant group differences (p< .05)	9/10	10/10	9/10	4/4
		Q_t Homogeneity Index[d]	27.43*	28.65*	52.37*	12.04*
		I^2	67.19	68.59	82.81	75.10

[a]- Effect size, Hedges *g*. All scores are scaled so that a positive effect size indicates greater impairment in the ADHD group.

[b]- Diagnostic criteria used to define the ADHD group

[c]- Note that Staikova et al. (2013) reported 1 missing data in the control group for the expressive measure (N= 34/28).

[d]- The Q_t statistic (Hedges and Olin, 1985) is a measure of the probability that the variance in effect sizes across studies is attributable to sampling error.

[NS]- Non significant result (*p*>.05)

*- Indicates significant heterogeneity of effect size for reasons other than sampling error (p<.01)

I^2- The I^2 index can be interpreted as the percentage of the total variability in a set of effect sizes due to true heterogeneity, that is, to between-studies variability.

Figure 1. PRISMA flow diagram of study identification and selection.

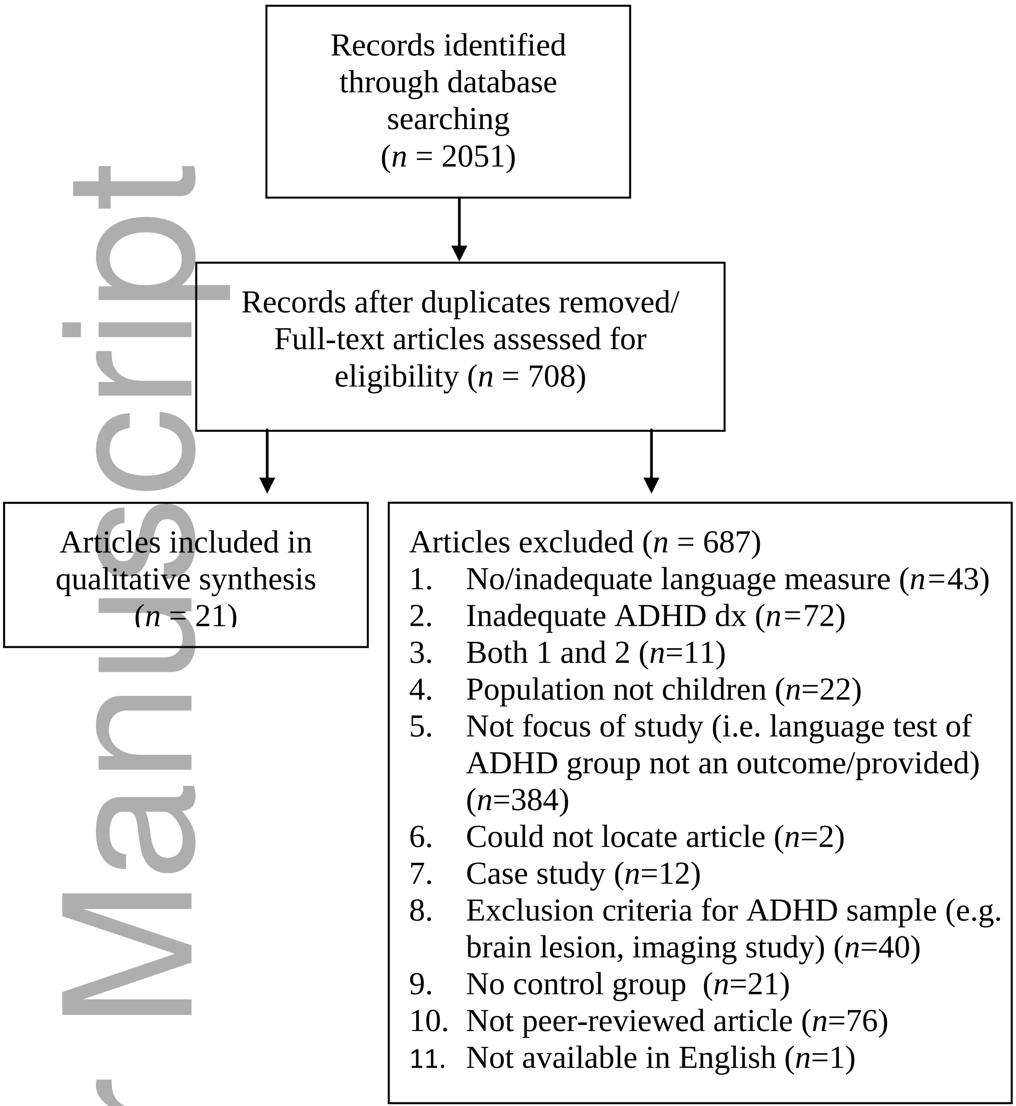
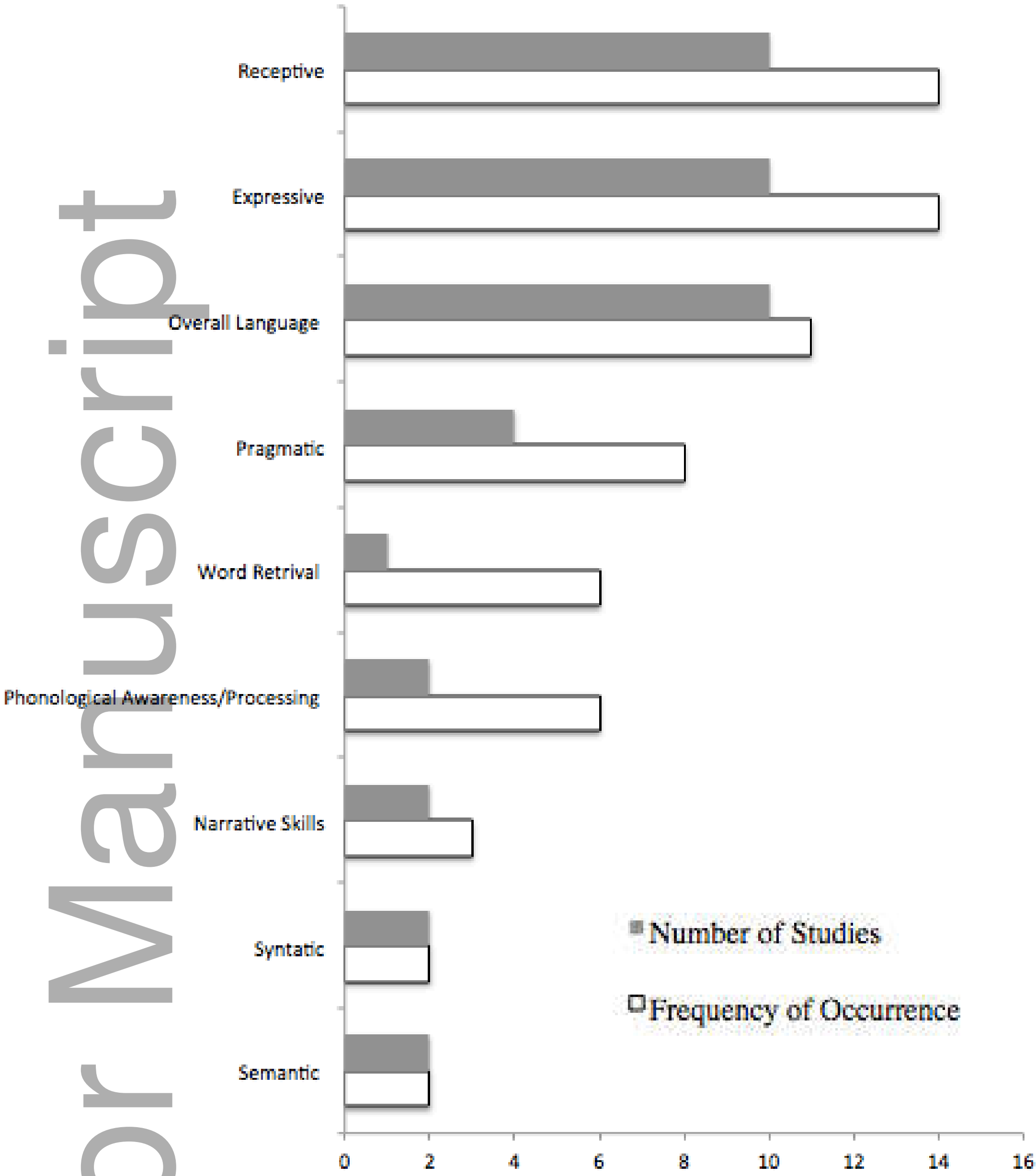
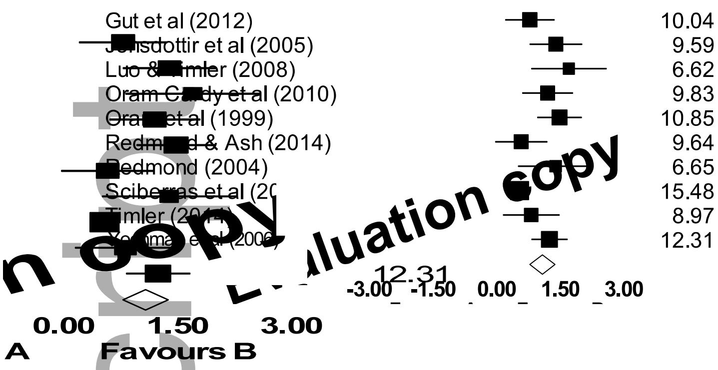


Figure 2. Type and Frequency of Language Measures used in the Included Studies.



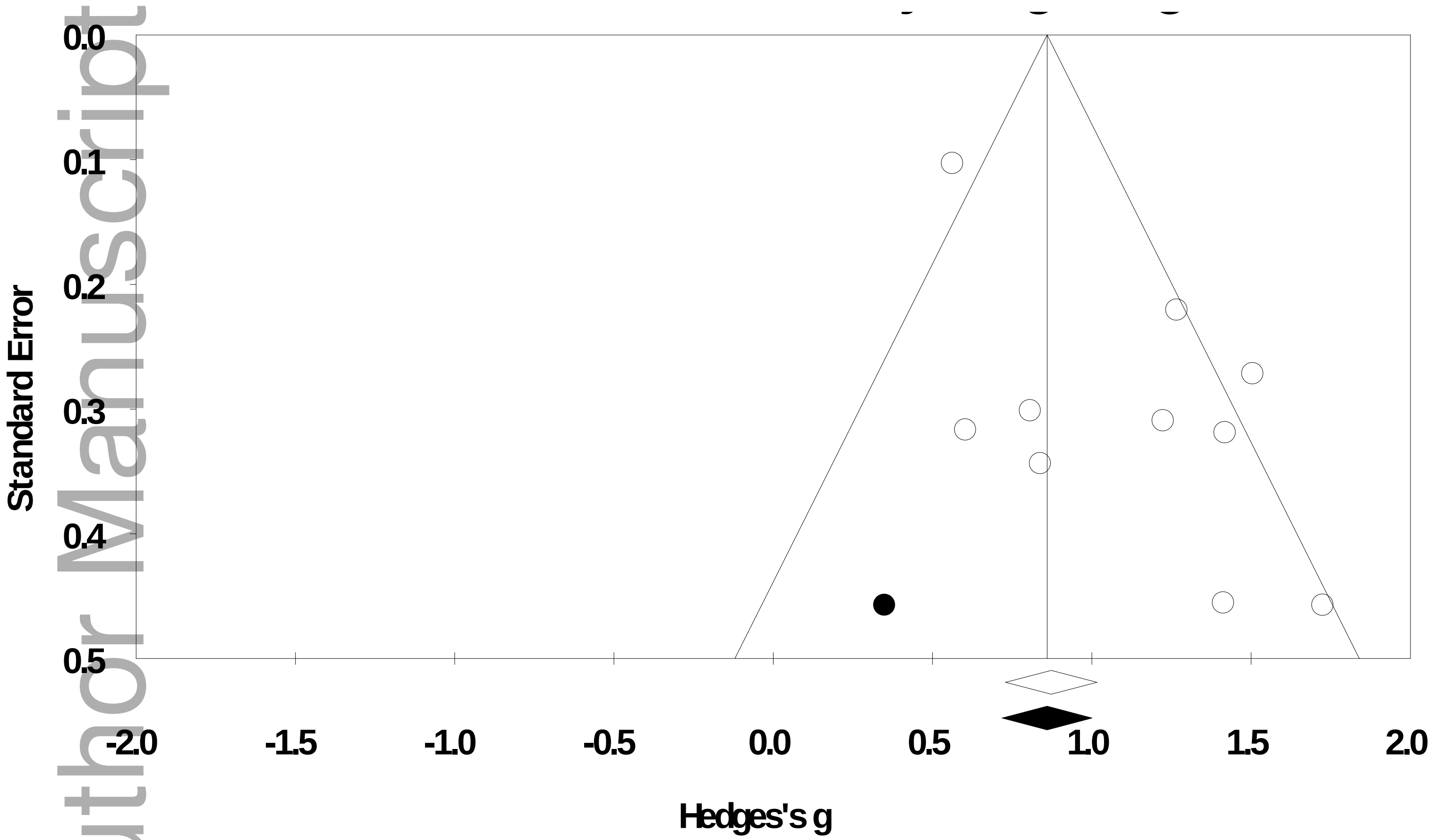
Nb. Frequency of occurrence refers to the number of times a given language measure was used across the studies.

Figure 3. Forest Plot by Language Domain, Hedges's g and 95% Confidence Intervals.



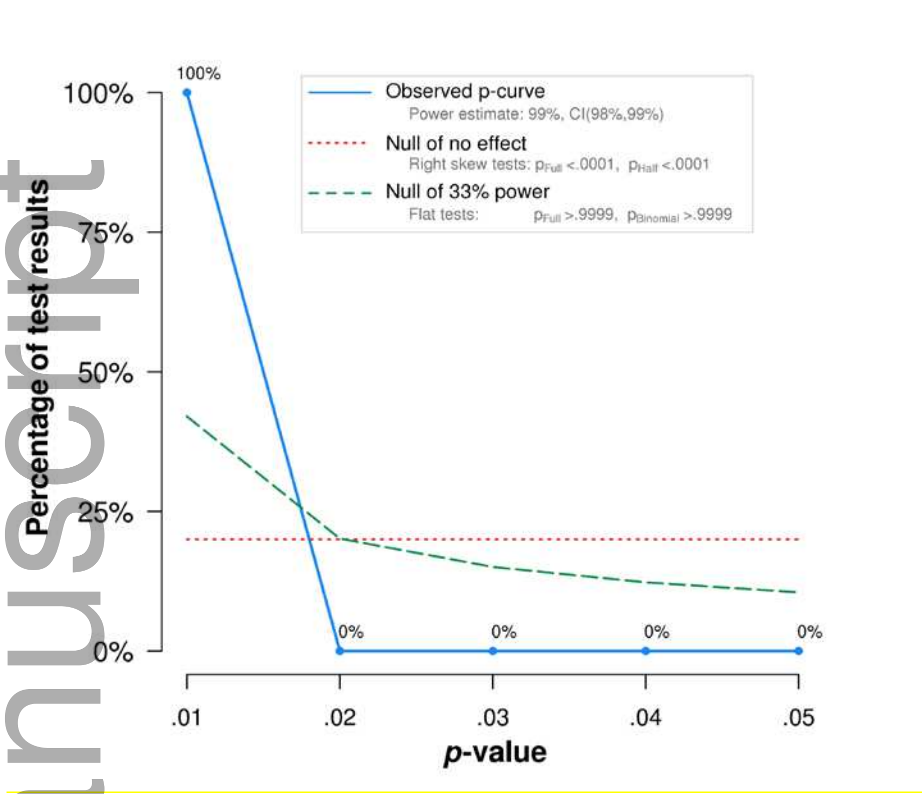
Nb. Studies have been given a relative weight using the random effects model, which ensures that individual studies are not weighed purely based on sample size as this may lead to inflated estimates. Adjustments are made for respective effect sizes. The black squares refer to each individual study, the size of which corresponds to their relative weightings. The black lines bisecting the square refer to their 95% confidence intervals. The white diamond refers to the overall mean effect size for each domain. '0.00' represents the line of no effect (i.e., no difference between the control and ADHD effect sizes found in each study). The area to the left of the line of no effect represents the ADHD performing better than the Control group in the language measures. The area to the right of the line of no effect represents the ADHD performing poorer than the Control group.

Figure 4. Funnel Plot of Standard Error by Hedges's *g* Effect Size for Overall Language Domain.



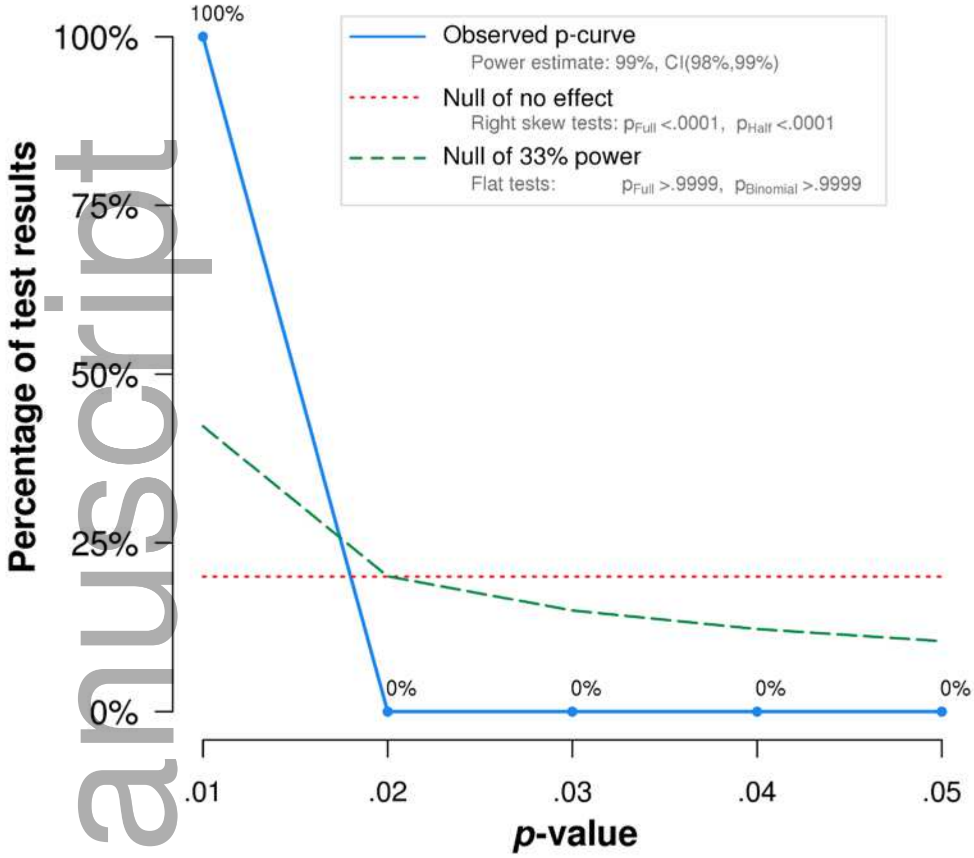
Nb. The circles refer to the studies (white- observed studies; black- study added by the Duval & Tweedie Trim and Fill approach to adjust for publication bias). The white diamond refers to observed values. The black diamond refers to adjusted mean effect size values corrected for publication bias.

Figure 5. P-curve for 9 Overall Language Effects



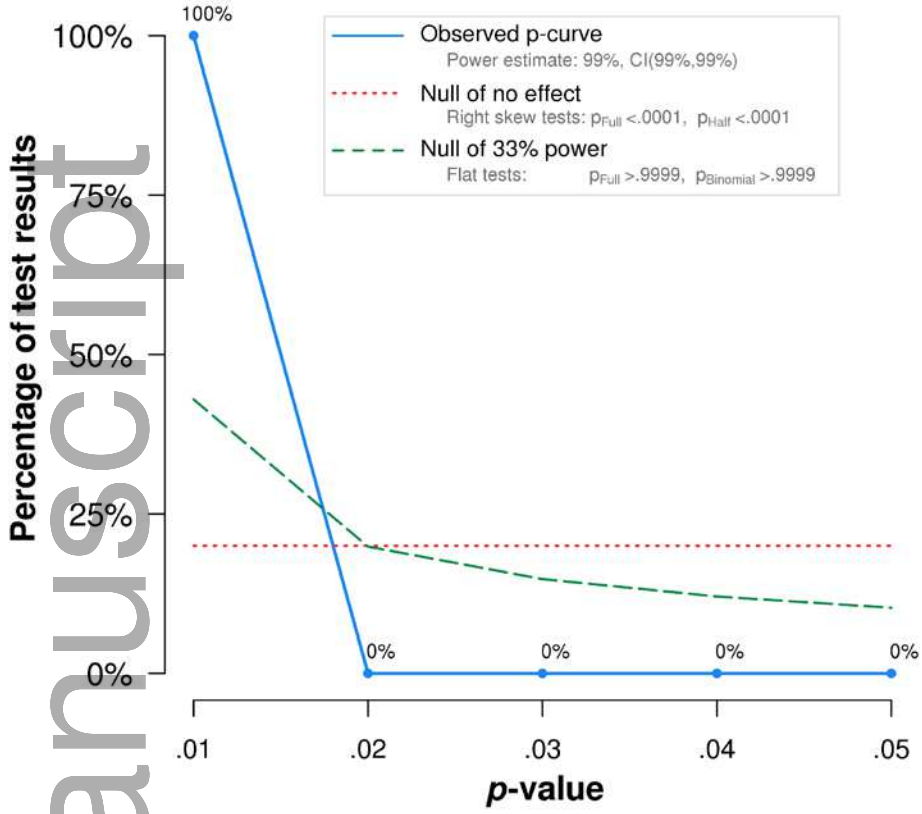
Nb. The graph shows distribution of the p-curve changes according to sample size and effect size. As *p* values approach non-significance (i.e., the α .05 cut-off), the skew becomes more right sided. The observed *p-curve* includes nine statistically significant studies ($p < .025$). One study was excluded from the *p-curve* analysis because it was $p > .05$. Significant right skew ($p < .0001$) was detected for this body of studies indicating that there is sufficient evidentiary value for a difference between ADHD and control children on the overall language measures. The findings also support the notion that publication bias and/or *p* hacking has not influenced the results. Unequal variance was assumed for the t-tests used to produce this *p-curve*.

Figure 6. P-curve for 10 Expressive Language Effects



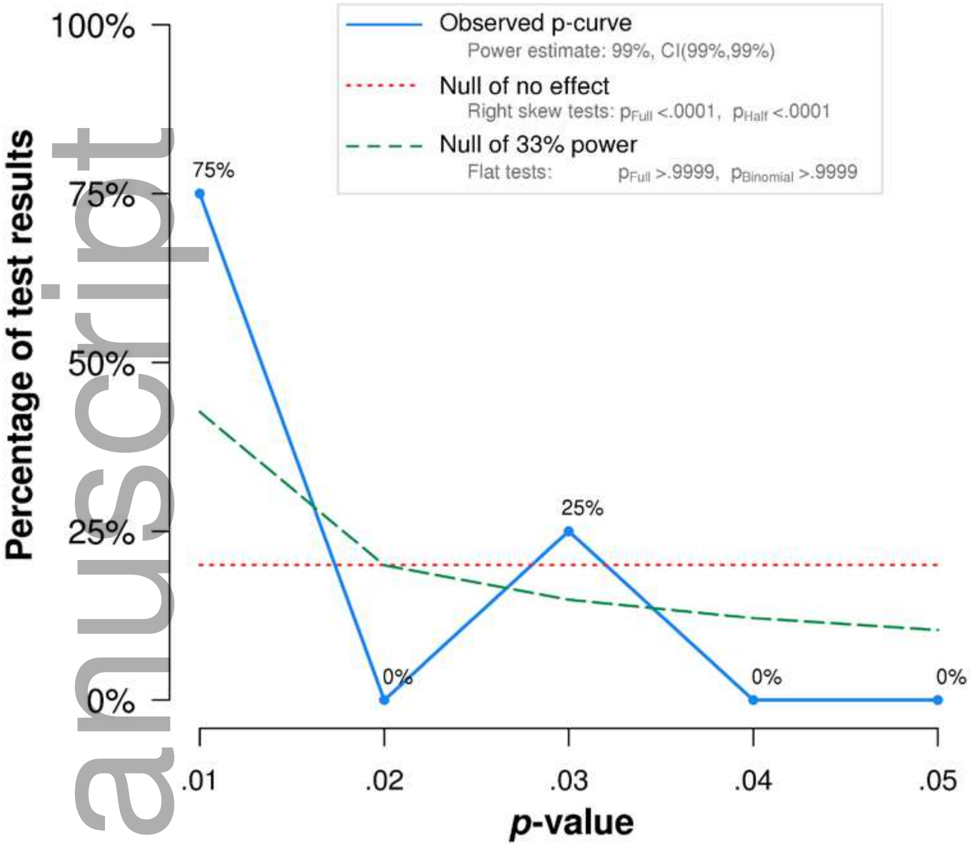
Nb. The observed *p-curve* includes 10 statistically significant studies ($p < .025$). Significant right skew ($p < .0001$) was detected for this body of studies indicating that there is sufficient evidentiary value for a difference between ADHD and control children on the expressive language measures. Unequal variance was assumed for the t-tests used to produce this *p-curve*.

Figure 7. P-curve for 9 Receptive Language Effects



Nb. The observed *p-curve* includes nine statistically significant results (p<.025). One study was excluded from the *p-curve* due to p > .05. Significant right skew (p < .0001) was detected for this body of studies indicating that there is sufficient evidentiary value for a difference between ADHD and control children on the receptive language measures. Unequal variance was assumed in this model.

Figure 8. P-curve for 9 Pragmatic Language Effects



Nb. The observed *p-curve* includes four statistically significant outcome measures from the pragmatic language domain, all of which of which were $p < .025$. Significant right skew ($p < .0001$) was detected for this body of studies indicating that there is sufficient evidentiary value for a difference between ADHD and control children on the pragmatic language measures. Unequal variance was assumed in this model.