Do research studies in the UK reporting child neurodevelopment adjust for the variability of assessors

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DO RESEARCH STUDIES IN THE UK REPORTING CHILD NEURODEVELOPMENT ADJUST FOR THE VARIABILITY OF ASSESSORS? A SYSTEMATIC REVIEW.

Abbreviated title: assessor variability

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ABSTRACT

Aim Neurodevelopment is a key outcome for many childhood trials and observational studies. Clinically important decisions may rest on finding relatively small differences in neurodevelopment between groups receiving complex and costly interventions. Our purpose was to determine whether studies which measure neurodevelopment report the numbers, training and auditing of assessors and, for multiple assessor studies, whether the results were adjusted and if so by which method?

Method Systematic review. Electronic searches were conducted using Medline, Embase, Cinahl, PsycINFO and the Cochrane library. A study was eligible if it reported neurodevelopmental outcome in children resident in the UK, ≤18 years and was published 2000-2013. Trials and observational studies were included.

Results 307 full papers were reviewed; 52% of papers did not report the number of assessors used, 21% used a single assessor and 27% used multiple assessors; 35% mentioned that assessors were trained in use of the neurodevelopmental tool, 13% of assessors were audited, only 1% of studies adjusted statistically for the number of assessors.

Interpretation At the very least, the quality of reporting the use of assessors in these research publications is poor; at worst, the variability of assessors may mask the true relationship between an intervention/observation and neurodevelopmental outcome.

200 words

Key words: neurodevelopmental assessment, variability, children

WHAT THIS PAPER ADDS

- UK studies published since 2000 which report neurodevelopmental outcome inadequately describe the training and audit procedures used with their assessors.
- Very few studies consider the potential impact on results of using multiple assessors and very few studies adjust statistically for the number of assessors used.
- Variability in assessor performance may obscure the true neurodevelopmental status of infants; it is incumbent on researchers to provide evidence of the robustness of their data.

Neurodevelopment is a key outcome for many randomised controlled trials and other research studies involving infants and children. Clinically important decisions can rest on finding a relatively small difference in neurodevelopment between groups arising from complex and costly interventions. Neurodevelopment is frequently used as a primary or secondary outcome in neonatal and paediatric studies as it provides quantifiable evidence of functional achievement; it is also used widely in other settings, such as education, social and psychological research.

There is a plethora of ways to measure neurodevelopment ranging from self-completion questionnaires by either the child or parent, to researcher administered tests. It is well recognised that self-completion and survey questionnaires can introduce bias to the test results;[1] but equally assessments which are administered by researchers are not immune to bias (i.e. inter-observer variability). The likelihood of inter-observer bias is acknowledged in the manuals of most neurodevelopmental tests, and guidance in test administration is given which is designed to minimise this bias. The guidance typically emphasises the need for assessors to follow a standard protocol and to be trained to a criterion level of proficiency. Nevertheless, variability in assessor performance may remain.

Is assessor variability simply a theoretical problem or can it lead to erroneous results and unwarranted conclusions? As part of an on-going investigation of the relationship between postnatal thyroid hormone levels and neurodevelopment, Delahunty et al[2] assessed and reported the developmental status of 442 children using three assessors. The children were evaluated at 5.5 years using the McCarthy Scales[3] which report the General Cognitive Index, which is derived from the verbal, perceptual performance and quantitative sub-scales, and separate motor and memory scales. Twenty-six variables known to confound neurodevelopment assessment were included in a univariate general linear regression model including gestational age, neonatal illness, hospital of birth (which provided a measure of geographical location), parental and lifestyle characteristics (including an objective measure of maternal intelligence, information about maternal depressive illnesses and number of months breastfeeding), significant life events and assessor. The regression modelling showed that assessor introduced variability which had a significant, independent, impact on three of the scales (motor, memory and verbal) which resulted in a score variation of between 7 and 8 points.[2] These scales have a population mean of 50 and a standard deviation of 10[3] thus assessor variability was statistically, and potentially clinically, significant. The mean scores of all of the scales were slightly inflated when the scores were not adjusted for assessor (Delahunty et al unpublished observations). The key outcome - low thyroxine levels - showed a significant and independent association with the perceptual performance scale only when the regression model did not include assessor variability. Hence, not adjusting for the variability introduced by the assessors in that dataset leads to a falsely positive association. Critically, these associations were seen in a study which at the outset had striven to minimise assessor variation; the psychologists were well trained in the use of the McCarthy Scales and their performance was regularly audited. In other studies, where training and audit of assessor performance may not be undertaken, assessor variability might be more marked or might operate differently, masking an affect when one is in fact present.

With so many studies using neurodevelopment as a primary or secondary end point, we wished to determine whether this potential source of variability in outcome measure was

acknowledged in published studies and whether any statistical adjustment was made in the analyses. We therefore decided to review a sample of the literature to determine:

1. whether studies measuring neurodevelopment report the number of assessors used;
2. whether studies report that assessors are trained in the use of the neurodevelopmental tools;
3. whether the assessors are audited in the use of the neurodevelopmental tool during the study; and,
4. in studies which use more than one assessor, are the results adjusted and if so by which method.

METHOD

Eligibility criteria

We aimed to review all published research studies which described performing neurodevelopmental assessments in children ≤18 years. Papers were included if they were published between January 2000 and September 2015; this date restriction was to limit the number of studies. As globally even this number of years would generate a huge number of studies we restricted our selection to studies undertaken in the UK; if the study was multi-country we abstracted, where possible, information pertaining to the UK participants. All study designs were eligible, except case reports and case studies. Because we were primarily interested in the potential for assessor variability, we excluded studies which assessed neurodevelopment exclusively from questionnaires completed by the child/parent/carer, and those which used only an internet or web based interface.

Definition of outcome terms

The neurodevelopmental tests used had to measure some aspect of neurodevelopmental function such as cognition or motor development (Table 1).

To be classified as 'trained' the paper had to state that specific training for the neurodevelopment tool was undertaken by the assessor(s). 'Implied training' was categorised as use of a professional term when describing the assessors such as paediatrician, researcher or psychologist, without evidence of specific training in the use of the neurodevelopmental tool. Audit was classified as measurement of assessor performance during the study, with comparison against a (gold) standard or against another assessor. The quantitative measure for assessor variability was whether or not the study had adjusted for the number of assessors statistically, such as by using assessor as an explanatory variable in regression analyses. If studies reported measuring inter-assessor variability we classified this either as 'training' if it occurred before the start of data collection, or as an 'audit' of assessor performance, if it occurred during data collection. The type of study was recorded as controlled trial (randomised or not-randomised), cohort, case-comparison or 'other' (e.g. cross-sectional and retrospective cohort).

Information sources and search strategy

The search strategy was developed by RK and used, with appropriate modification, with five databases: Medline, EMBASE, CINAHL, PsycINFO and the Cochrane Central Register of Controlled Trials. The searches were last run on 15/09/2015.

The search strategy was developed using the PICOS framework[4] (Table 1). MeSH terms were generated for each of the PICOS subject headings and formatted according to which generated the most results, either by exploding or searching the MeSH term as a major concept. If a search term was not available as a MeSH heading it was searched as a keyword. The MeSH terms for each PICOS subject heading were combined using Boolean terms enabling multiple combinations of terms to be searched at once. The reference lists of reviewed papers were scanned to look for papers that had been missed in the electronic searches.

Study selection, data abstraction and risk of bias assessment

The titles and abstracts of all articles were screened and assessed for relevance according to the inclusion criteria (Table 1). Selected articles identified after the initial screen were retrieved in full text. Data were abstracted about the numbers of assessors used, whether the assessors were trained in the use of the neurodevelopmental tool, whether the neurodevelopmental outcome was statistically adjusted for the numbers of assessors used, and whether assessor performance was audited.

The first screen was performed in full by RK. The second screen of full text articles and data abstraction was performed independently by RK and FLRW. Discrepancies between the reviewers were resolved by discussion.

As we were trying only to ascertain whether or not researchers noted, accounted for and reported the number of assessors undertaking neurodevelopmental testing in their work, other aspects of the methodological robustness of the included articles were not reviewed. Simple descriptive statistics were used to describe the data.

RESULTS

During the first search 13,263 papers were identified; following exclusions, 307 papers remained for full review (Figure 1.) The description and reference list for the 307 papers is available online (Appendix).

One-half of the papers (159/307, 52%) did not report how many assessors undertook the neurodevelopmental testing; 21% of papers (65/307) reported using a single assessor and 27% (83/307) used multiple assessors (Figure 2). Of the 83 papers reporting the use of multiple assessors, 30 reported the exact number; the median number of assessors used in that group was 3 and the range 2-31. The median number of children assessed in the studies reporting (definite and implied) use of a single assessor was 64, range 7 to 782; in studies with multiple assessors it was 186, range 17 to 6455; and in studies that did not mention the number of assessors involved, the median number of children in the study was 90, range 10 to 12,449.

Very few (17%, 52/307) studies reported specifically training their assessors; however several papers (18%, 56/307) implied that assessors might be trained through use of phrases such as ‘research psychologists’, ‘experienced paediatricians’ and ‘experienced speech and language therapists’ when describing who undertook the testing. The remaining 199 studies (65%) made no mention about assessor training (Figure 2).

Few studies (13%, 40/307) reported auditing the assessors during the assessment period (Figure 2). Those that did audit used two main approaches; either a sample of tests were re-assessed by an independent observer and a statistic such as inter-rater variability calculated (for example percentage agreement or Cohen's Kappa), or an assessment was video-taped and the performance of the assessor reviewed by an independent expert.

Only three (1%, 3/242) of the studies which reported using multiple assessors or which failed to report the number of assessors used, made statistical adjustment for the number of assessors in their analysis. Each study used a different method for adjustment. Lazarus et al,[5] who reported a randomised controlled trial, controlled for inter-assessor variation in two ways. The first was by adjusting each assessor's calculated IQ score by the difference between the population mean IQ score (which was set at 100) and that assessor's mean IQ score derived from their control group. For example, if the mean IQ for the control group for one assessor was 105, then all IQ scores derived by that assessor were reduced by 5 points and analyses were carried out on the adjusted scores. The second was by analysis of Z scores (observed IQ minus the mean, divided by the standard deviation, according to assessor). Delahunty et al's[2] cohort study adjusted for possible assessor variation by including the assessor as an explanatory variable in univariate general linear regression models of McCarthy Scale scores.[3] Finally, Gordon et al's[6] cohort study adjusted for possible variation by using the average score of the assessors to derive a mean neurologic examination score.

The majority of studies used a case-comparison (40%) or a cohort (37%) study design (Table 2). A higher proportion of trials (randomised, non-randomised, definite and implied) used trained assessors compared to case-comparison studies (Fischer Exact p=0.03) but not when compared to cohort studies (Fischer Exact p=0.20); the training status of assessors in case-comparison and cohort studies did not differ appreciably (Fischer Exact p=0.18). Whether or not a study was audited did not differ according to the study design (trial versus cohort Fischer Exact p=0.30, trial versus case-comparison Fischer Exact p=0.36, and cohort versus case-comparison Fischer Exact p=0.98).

DISCUSSION

This comprehensive review identified a large number of eligible studies, but found that the majority of authors do not describe in sufficient detail the number, quality (e.g. training and adherence to guidelines) and potential impact (e.g. statistical adjustment) of the assessors they employ to generate the key outcome measures. Using the total number of papers identified in the search as the denominator reveals four key points. First, only 48% of the studies gave quantitative information about the number of assessors that they employed. Secondly, only 35% of studies provided any indication that assessors had received training. Thirdly, only 13% of the studies reported that assessor performance had been audited. And, lastly, only 1% of the studies adjusted statistically for the number of assessors in their analyses (the denominator excludes single assessor studies). Using studies that reported using multiple assessor studies as the denominator (N=83) however only increases the percentage of studies that statistically adjusted their data to 4%.

It could be argued that using the total number of papers identified in the review (rather than the subsection which provided assessor information) artificially underestimates the proportions reported in this review. However, the outcomes reported here (assessor

number, training status, audit and analytical detail) are so basic that the counter argument is that they should be included in any well written methods section. It might be reasonable to assume that researchers are competent in administering assessments, but it is important to provide information about how this competence is achieved, especially when there are several assessors who may differ in their experience, ability and diligence.

Only 40 studies reported whether their assessors were audited in some way. Audit is important to ensure the reliability of measures and that standard procedures are consistently followed for the duration of the study. Audit is especially important when multiple assessors are involved in order to monitor and correct (through feedback) any variation between individual assessors. It could be debated that the 40 studies which reported auditing their assessors, and especially those that reported inter-rater variability measures, should be classified as having adjusted for assessor variability - using the logic that a high rater agreement by definition means that assessor variability was negligible. However audit is generally undertaken in only a sample of the assessments (random or otherwise, small or large) and can vary appreciably in comprehensiveness and extent. In some instances, inter-rater reliability is established by reporting the correlation between assessor scores. While such a method can indicate whether assessor performance is related, it is inadequate for audit because it fails to detect any difference in mean scores or the closeness of assessor ratings.[7] Thus, while audit based on only a sample of assessments and or assessors is appropriate for evaluating assessor reliability, it cannot be used to adjust for number of assessors in statistical analyses.

Slightly more than half the studies provided no information about the number of assessors used in the study. However, the median number of children in these studies was considerably larger than in single-assessor studies, and it is therefore likely that many which provided no information did include multiple assessors. Of the studies that used multiple assessors only three adjusted statistically for multiple assessors. Even if the number of studies which describe auditing assessor performance are added to those which used a single assessor and those which statistically adjusted outcome, two-thirds of the reviewed papers still failed to mention and account for assessor variability.

Clinical and research governance, with independent oversight, is integral in the research design and management of clinical trials, and many are run through experienced and accredited clinical trial units. In view of this, it might have been expected that trials would be more likely than other study designs to use trained assessors, regularly audit performance, adjust results statistically as appropriate and, most importantly, describe such an approach in their published articles. This expectation was not supported by the findings of this review.

We made no attempt to contact authors to obtain clarification, and it is very likely that many of the investigators did indeed train their assessors in the use of the developmental tools, but simply failed to note this in their paper. (For this reason we included the classification of implied training; although we recognize that this is not a good example of reporting accuracy.) Many too will have monitored, in some way, the performance of assessors. However, it is less likely that investigators have adjusted statistically for the assessors as this would have been described in the methods or be evident in the results. Overall therefore the proportions reported in this systematic review are likely to be

underestimates and portray a bleaker picture than reality. Attention to detail when writing methodology sections in papers could remove this underestimate instantly.

No study involving neonates and children is straightforward, many are clinically and logistically complex, all are fiscally and many emotionally costly. Accurate and correct interpretation of outcome is an underlying principle of good science. So is the poor reporting of assessors highlighted in this review a theoretical or real problem? The analytical methods of two of the three studies which adjusted for assessor variability identified in this review suggest that the problem is real. The study by Delahunty et al,[2] as described in the introduction, showed a clear effect of assessor variability on the outcomes. The review of the supplemental data posted online by Lazurus et al[5] suggests that although the study adjusted for within assessor variation that some between assessor variation may have remained. We found two general approaches used for adjusting assessor variability. One is to adjust the raw scores before the analyses;[5,6] the other is to include assessor as a variable in the statistical analysis.[2]

We reviewed only three studies that considered, found and then adjusted for assessor variability, and consequently there is only very weak evidence that assessor variability is a problem. However, the evidence will remain poor until researchers routinely investigate and report the impact on their results of using multiple assessors. If it is arguable that the assessor variability is a proxy for some other direct and real association (such as socio-economic factors related to geographical location) then this should be reflected in the researchers' interpretation of their data. Whatever the interpretation, it is incumbent on researchers to reassure readers that their research findings are robust and until they investigate the impact of multiple assessors on their data they cannot provide the reassurance that their findings are accurate. It is very easy to record the number of assessors used in a study, and inclusion of assessor as a variable is a simple and effective statistical method of considering this source of potential variability. How a researcher interprets this variability is dependent on identifying its true source.

Three hundred and seven papers were included in this systematic review (although almost 15 times that number, globally, reported using neurodevelopmental assessment as part of their study design). At the very least, the quality of reporting the use and impact of assessors in research publications is poor; at worst, the variability of assessors may mask the true relationship between an intervention/observation and neurodevelopmental outcome. We suggest that it should become the norm for researchers to include a 'procedural' paragraph in the methods section of all papers, which clearly describes the number of assessors involved in the study, how they were trained, how they were audited, and how, if appropriate, the data were adjusted to account for the potential variability produced by multiple assessors. Such a requirement should be added to methodological guidelines and check lists such as CONSORT, PRISMA and STROBE.

Finally, this paper reviewed studies undertaken and reported in the UK and a question remains therefore about whether these findings are generalizable to other settings. While not definitive, we undertook a brief global review of papers published in 2015. Of the first 25 non-UK papers listed in Medline and EMBASE 5/25 reported definitely and a further 4/25 implied training the assessors; 2/25 reported auditing the assessors; and, 1 study adjusted

for multiple assessors. These findings are very similar to those of the UK and suggest that the findings for the UK are very likely applicable to researchers in this field worldwide.

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TABLE 1: Inclusion criteria for considering studies in the review using the picos* framework

PICOS component	Inclusion criteria	Comment
Participant	Studies in which participants were assessed at ≤18 years UK subjects	If the group mean age was >18 years the paper was excluded.
Assessment	Neurodevelopmental outcome assessed using valid assessment tools within any of the fields of: • Cognition • Motor skills • Memory • Perception • Emotion • Attention • Executive function • Behaviour • Psychological • Psychomotor development • Mental developmental • Verbal and communication development • Sensorineural impairments including: hearing deficit and visual acuity	Valid i.e. the tool was in the public domain, available for use and published in academic articles
Study design	Randomised controlled trials, Observational studies (Cohort, Case-control, Cross-sectional)	Case reports and case studies were excluded
Report characteristics	Published between 2000-2013, English Language, and setting in the UK	

*PICOS **P**articipants, **I**ntervention, **C**omparators, **O**utcomes, **S**tudy design [5]

TABLE 2: Relationship between study design and reported audit and training of the assessors

Study Design	Number of papers reviewed	Audit reported		Training reported		
		Yes	Not stated	Yes	Implied	Not stated
Trial -randomised	21	1	20	6	6	9
Trial-not randomised	2	-	2	1	-	1
Cohort	114	17	97	24	22	68
Case-comparison	122	17	105	16	21	85
Other	48	5	43	5	7	36
Sub total		40	267	52	56	199
Total	307	307		307		

FIGURE CAPTIONS

Figure 1

Numbers of articles sourced at each stage of the systematic review and reasons for exclusion

Figure 2

Number of UK studies which have reported neurodevelopment as an outcome of an intervention or condition between 2000 and 2013 according to number of assessors

Table 2a: Full reference list of the 307 papers that were reviewed

1	Adams A-M, Gathercole SE. Limitations in working memory: implications for language development. *Int J Lang Comm Dis* 2000; **35**: 95-116.
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Table 2b: Main outcomes of each of the 307 papers reviewed.

Author	Assessors trained	Assessors audited	Study adjusted for multiple assessors
Conti-Ramsden et al[27]	✓ Yes -definitely	Not stated	Not stated
Pickstone et al[29]	✓ Yes -definitely	✓ Yes -definitely	Not stated
Minnis et al[64]	✓ Yes -definitely	✓ Yes -definitely	Not stated
Wood et al[244]	✓ Yes -definitely	✓ Yes -definitely	Not stated
Green et al[19]	✓ Yes -definitely	✓ Yes -definitely	Not stated
Greenough et al[20]	✓ Yes -definitely	Not stated	Not stated
Foulder-Hughes et al[28]	✓ Yes -definitely	Not stated	Not stated
Thomas et al[30]	✓ Yes -definitely	Not stated	Not stated
Morley et al[40]	✓ Yes -definitely	Not stated	Not stated
Dyet et al[56]	✓ Yes -definitely	Not stated	Not stated
Foster et al[57]	✓ Yes -definitely	Not stated	Not stated
Rhodes et al[66]	✓ Yes -definitely	✓ Yes -definitely	Not stated
Simonoff et al[67]	✓ Yes -definitely	Not stated	Not stated
Chiat et al[72]	✓ Yes -definitely	✓ Yes -definitely	Not stated
Emond et al[77]	✓ Yes -definitely	Not stated	Not stated
McCann et al[80]	✓ Yes -definitely	Not stated	Not stated
Johnson et al[120]	✓ Yes -definitely	Not stated	Not stated
Delahunty et al[131]	✓ Yes -definitely	✓ Yes -definitely	✓ Yes -definitely
Nation et al[139]	✓ Yes -definitely	Not stated	Not stated
Johnson et al[145]	✓ Yes -definitely	Not stated	Not stated
Fellick et al[151]	✓ Yes -definitely	Not stated	Not stated
Cooke et al[154]	✓ Yes -definitely	Not stated	Not stated
Maharasingam et al[155]	✓ Yes -definitely	Not stated	Not stated
Ellis et al[171]	✓ Yes -definitely	Not stated	Not stated
Strain et al[174]	✓ Yes -definitely	✓ Yes -definitely	Not stated
Skuse et al[176]	✓ Yes -definitely	Not stated	Not stated
Edwards et al[270]	✓ Yes -definitely	✓ Yes -definitely	Not stated
Hart et al[271]	✓ Yes -definitely	✓ Yes -definitely	Not stated
Owens et al[173]	✓ Yes -definitely	✓ Yes -definitely	Not stated
Snowling et al[190]	✓ Yes -definitely	✓ Yes -definitely	Not stated
Bitsakou et al[191]	✓ Yes -definitely	✓ Yes -definitely	Not stated
Turton et al[195]	✓ Yes -definitely	✓ Yes -definitely	Not stated
Vollmer et al[196]	✓ Yes -definitely	Not stated	Not stated
Arseneault et al[197]	✓ Yes -definitely	✓ Yes -definitely	Not stated
Durkin et al[207]	✓ Yes -definitely	Not stated	Not stated
Horwood et al[217]	✓ Yes -definitely	Not stated	Not stated
Kirby et al[222]	✓ Yes -definitely	Not stated	Not stated
Reed et al[227]	✓ Yes -definitely	Not stated	Not stated
Pearson et al[237]	✓ Yes -definitely	✓ Yes -definitely	Not stated
Sutcliffe et al[241]	✓ Yes -definitely	Not stated	Not stated
Kirby et al[187]	✓ Yes -definitely	Not stated	Not stated
Marlow et al[162]	✓ Yes -definitely	Not stated	Not stated
Laing et al[21]	✓ Yes -possibly	Not stated	Not stated
Burt et al[36]	✓ Yes -possibly	Not stated	Not stated
Johnson et al[137]	✓ Yes -possibly	Not stated	Not stated
Williams et al[2]	✓ Yes -possibly	Not stated	Not stated
Bennet et al[5]	✓ Yes -possibly	Not stated	Not stated
Sutcliffe et al[16]	✓ Yes -possibly	Not stated	Not stated
Michelotti et al[22]	✓ Yes -possibly	Not stated	Not stated
Dimitriou et al[17]	✓ Yes -possibly	Not stated	Not stated
Gordon et al[18]	✓ Yes -possibly	✓ Yes -definitely	✓ Yes -definitely
Lazarus et al[44]	✓ Yes -possibly	Not stated	✓ Yes -definitely
Telford et al[68]	✓ Yes -possibly	Not stated	Not stated
Vollmer et al[69]	✓ Yes -possibly	Not stated	Not stated

Author	Assessors trained	Assessors audited	Study adjusted for multiple assessors
Boucher et al[85]	✓ Yes -possibly	Not stated	Not stated
Chiat et al[89]	✓ Yes -possibly	Not stated	Not stated
Dorris et al[91]	✓ Yes -possibly	Not stated	Not stated
Eglinton et al[92]	✓ Yes -possibly	Not stated	Not stated
Figueras et al[93]	✓ Yes -possibly	Not stated	Not stated
Ford et al[94]	✓ Yes -possibly	Not stated	Not stated
Myers et al[105]	✓ Yes -possibly	Not stated	Not stated
Williams et al[110]	✓ Yes -possibly	Not stated	Not stated
Hall et al[118]	✓ Yes -possibly	Not stated	Not stated
Sayal et al[124]	✓ Yes -possibly	Not stated	Not stated
Tadic et al[127]	✓ Yes -possibly	✓ Yes -definitely	Not stated
Boardman et al[128]	✓ Yes -possibly	Not stated	Not stated
Bromley et al[129]	✓ Yes -possibly	Not stated	Not stated
Cullen et al[130]	✓ Yes -possibly	Not stated	Not stated
Hogan et al[134]	✓ Yes -possibly	Not stated	Not stated
Mackie et al[138]	✓ Yes -possibly	Not stated	Not stated
Rosen et al[140]	✓ Yes -possibly	Not stated	Not stated
Van Kooij et al[150]	✓ Yes -possibly	Not stated	Not stated
Barnett et al[156]	✓ Yes -possibly	Not stated	Not stated
Brown et al[157]	✓ Yes -possibly	Not stated	Not stated
O'Brien et al[159]	✓ Yes -possibly	Not stated	Not stated
Deave[160]	✓ Yes -possibly	Not stated	Not stated
Camilleri et al[166]	✓ Yes -possibly	✓ Yes -definitely	Not stated
Coghill et al[168]	✓ Yes -possibly	Not stated	Not stated
Elison et al[254]	✓ Yes -possibly	Not stated	Not stated
Livingstone[260]	✓ Yes -possibly	Not stated	Not stated
Rogers et al[264]	✓ Yes -possibly	Not stated	Not stated
Roth et al[266]	✓ Yes -possibly	Not stated	Not stated
Cleland et al[146]	✓ Yes -possibly	Not stated	Not stated
Windfurhr et al[26]	✓ Yes -possibly	✓ Yes -definitely	Not stated
Haines et al[10]	✓ Yes -possibly	Not stated	Not stated
Sonuga-Barke et al[192]	✓ Yes -possibly	✓ Yes -definitely	Not stated
Brown et al[193]	✓ Yes -possibly	Not stated	Not stated
Gale et al[210]	✓ Yes -possibly	Not stated	Not stated
Gale et al[211]	✓ Yes -possibly	Not stated	Not stated
Kini et al[213]	✓ Yes -possibly	Not stated	Not stated
Marlow et al[215]	✓ Yes -possibly	Not stated	Not stated
Roth et al[238]	✓ Yes -possibly	Not stated	Not stated
Bath et al[180]	✓ Yes -possibly	Not stated	Not stated
Adams et al[1]	Not stated	✓ Yes -definitely	Not stated
Botting et al[6]	Not stated	Not stated	Not stated
Fawcett et al[9]	Not stated	Not stated	Not stated
Henry[11]	Not stated	Not stated	Not stated
Hutton et al[12]	Not stated	Not stated	Not stated
Laws et al[13]	Not stated	Not stated	Not stated
Talcott et al[25]	Not stated	Not stated	Not stated
Viding et al[32]	Not stated	Not stated	Not stated
Bull et al[35]	Not stated	Not stated	Not stated
Isaacs et al[37]	Not stated	Not stated	Not stated
Fisher et al[42]	Not stated	Not stated	Not stated
Conti-Ramsden et al[55]	Not stated	Not stated	Not stated
Mackinley et al[62]	Not stated	Not stated	Not stated
Hughes et al[78]	Not stated	Not stated	Not stated
Joffe et al[79]	Not stated	Not stated	Not stated
Petrou et al[81]	Not stated	Not stated	Not stated
Stojanovik et al[82]	Not stated	✓ Yes -definitely	Not stated

Author	Assessors trained	Assessors audited	Study adjusted for multiple assessors
Deconinck et al[114]	Not stated	Not stated	Not stated
Adam et al[3]	Not stated	Not stated	Not stated
Allin et al[4]	Not stated	Not stated	Not stated
Briscoe et al[7]	Not stated	Not stated	Not stated
Conti-Ramsden[8]	Not stated	Not stated	Not stated
Rushe et al[14]	Not stated	Not stated	Not stated
Scott et al[15]	Not stated	Not stated	Not stated
Thomson[31]	Not stated	Not stated	Not stated
Vollmer et al[33]	Not stated	Not stated	Not stated
Adab et al[34]	Not stated	Not stated	Not stated
Mercuri et al[39]	Not stated	Not stated	Not stated
Nosarti et al[41]	Not stated	Not stated	Not stated
Gathercole et al[43]	Not stated	Not stated	Not stated
Rathbone et al[45]	Not stated	Not stated	Not stated
Halliday et al[46]	Not stated	Not stated	Not stated
Hick et al[47]	Not stated	Not stated	Not stated
Hogan et al[48]	Not stated	Not stated	Not stated
Lawlor et al[49]	Not stated	Not stated	Not stated
Rhodes et al[50]	Not stated	Not stated	Not stated
Stephens et al[51]	Not stated	Not stated	Not stated
Vinten et al[52]	Not stated	Not stated	Not stated
Allin et al[53]	Not stated	Not stated	Not stated
Archibold et al[54]	Not stated	Not stated	Not stated
Gale et al[58]	Not stated	Not stated	Not stated
Happe et al[59]	Not stated	Not stated	Not stated
Kuntsi et al[60]	Not stated	Not stated	Not stated
Loat et al[61]	Not stated	Not stated	Not stated
Millar et al[63]	Not stated	Not stated	Not stated
Pressler et al[65]	Not stated	Not stated	Not stated
Whitehouse et al[70]	Not stated	Not stated	Not stated
Barnett et al[71]	Not stated	Not stated	Not stated
Conti-Ramsden et al[73]	Not stated	Not stated	Not stated
Corriveau et al[74]	Not stated	Not stated	Not stated
Allin et al[83]	Not stated	Not stated	Not stated
Burns et al[87]	Not stated	Not stated	Not stated
Calvert et al[88]	Not stated	Not stated	Not stated
Gale et al[96]	Not stated	Not stated	Not stated
Gathercole et al[97]	Not stated	Not stated	Not stated
Gkoltsiou et al[98]	Not stated	Not stated	Not stated
Haque et al[99]	Not stated	Not stated	Not stated
Harris et al[100]	Not stated	Not stated	Not stated
Isaacs et al[101]	Not stated	Not stated	Not stated
Liegeois et al[102]	Not stated	Not stated	Not stated
Molesworth et al[103]	Not stated	Not stated	Not stated
Moore et al[104]	Not stated	Not stated	Not stated
Nosarti et al[106]	Not stated	Not stated	Not stated
Okereafor et al[107]	Not stated	Not stated	Not stated
Stojanovik et al[109]	Not stated	Not stated	Not stated
Auyeung et al[111]	Not stated	Not stated	Not stated
Baxter et al[112]	Not stated	Not stated	Not stated
Bishop et al[113]	Not stated	Not stated	Not stated
Edwards et al[115]	Not stated	Not stated	Not stated
Godfrey et al[116]	Not stated	Not stated	Not stated
Gregory et al[117]	Not stated	Not stated	Not stated
Isaacs et al[119]	Not stated	Not stated	Not stated
Meiser-Stedman et al[121]	Not stated	Not stated	Not stated

Author	Assessors trained	Assessors audited	Study adjusted for multiple assessors
Odd et al[122]	Not stated	Not stated	Not stated
Robinson et al[123]	Not stated	Not stated	Not stated
Sussman et al[125]	Not stated	Not stated	Not stated
Baird et al[126]	Not stated	Not stated	Not stated
Hayiou-Thomas et al[132]	Not stated	Not stated	Not stated
Ho et al[133]	Not stated	Not stated	Not stated
Hughes et al[135]	Not stated	Not stated	Not stated
Isaacs et al[136]	Not stated	Not stated	Not stated
Scope et al[141]	Not stated	Not stated	Not stated
St Clair et al[142]	Not stated	Not stated	Not stated
Cummings et al[143]	Not stated	Not stated	Not stated
Gooch et al[144]	Not stated	Not stated	Not stated
Scott et al[147]	Not stated	Not stated	Not stated
Skirrow et al[148]	Not stated	Not stated	Not stated
Sylva et al[149]	Not stated	Not stated	Not stated
Al-Dahhan et al[152]	Not stated	Not stated	Not stated
Gale et al[158]	Not stated	Not stated	Not stated
Hick et al[161]	Not stated	Not stated	Not stated
Schulte et al[163]	Not stated	Not stated	Not stated
Clark et al[167]	Not stated	Not stated	Not stated
Wilding et al[169]	Not stated	Not stated	Not stated
Archibold et al[170]	Not stated	Not stated	Not stated
Tan et al[175]	Not stated	Not stated	Not stated
Dawes et al[177]	Not stated	Not stated	Not stated
Mulder et al[178]	Not stated	Not stated	Not stated
Toland et al[245]	Not stated	Not stated	Not stated
Atkinson et al[246]	Not stated	Not stated	Not stated
Alloway [247]	Not stated	Not stated	Not stated
Bishop et al[248]	Not stated	Not stated	Not stated
Byrne et al[249]	Not stated	Not stated	Not stated
Coleman et al[251]	Not stated	Not stated	Not stated
Cottrell et al[252]	Not stated	Not stated	Not stated
Drew et al[253]	Not stated	Not stated	Not stated
Gallon et al[255]	Not stated	✓ Yes -definitely	Not stated
Happe et al[256]	Not stated	✓ Yes -definitely	Not stated
Harding et al[257]	Not stated	Not stated	Not stated
Holmes et al[258]	Not stated	Not stated	Not stated
Jarrold et al[259]	Not stated	Not stated	Not stated
McCartney et al[261]	Not stated	Not stated	Not stated
Milne et al[262]	Not stated	Not stated	Not stated
O'Connor et al[263]	Not stated	Not stated	Not stated
Rosen et al[265]	Not stated	Not stated	Not stated
Sugden et al [267]	Not stated	Not stated	Not stated
White et al[268]	Not stated	Not stated	Not stated
Wood et al[269]	Not stated	Not stated	Not stated
O'Hare et al[23]	Not stated	Not stated	Not stated
Shallice et al[24]	Not stated	Not stated	Not stated
Laws et al[38]	Not stated	Not stated	Not stated
Dockrell et al[75]	Not stated	Not stated	Not stated
Donaldson et al[76]	Not stated	Not stated	Not stated
Archbold et al[84]	Not stated	Not stated	Not stated
Bull et al[86]	Not stated	Not stated	Not stated
Froud et al[95]	Not stated	Not stated	Not stated
Stinton et al[108]	Not stated	Not stated	Not stated
Bosson et al[153]	Not stated	Not stated	Not stated
Flynn et al[164]	Not stated	✓ Yes -definitely	Not stated

Author	Assessors trained	Assessors audited	Study adjusted for multiple assessors
Brock et al[165]	Not stated	Not stated	Not stated
Haskell et al[172]	Not stated	Not stated	Not stated
Davis et al[90]	Not stated	Not stated	Not stated
Svirko et al[194]	Not stated	Not stated	Not stated
Barnett et al[198]	Not stated	Not stated	Not stated
Bayless et al[199]	Not stated	Not stated	Not stated
Chapman et al[200]	Not stated	Not stated	Not stated
Conti-Ramsden et al[201]	Not stated	Not stated	Not stated
Corbett et al[202]	Not stated	Not stated	Not stated
Cormack et al[203]	Not stated	Not stated	Not stated
Davidson et al[204]	Not stated	✓ Yes -definitely	Not stated
Christie et al[205]	Not stated	Not stated	Not stated
Dunkley et al[206]	Not stated	Not stated	Not stated
Edmonds et al[208]	Not stated	Not stated	Not stated
Cooke et al[209]	Not stated	Not stated	Not stated
Halsey et al[212]	Not stated	Not stated	Not stated
Hay et al[214]	Not stated	Not stated	Not stated
Hood et al[216]	Not stated	Not stated	Not stated
Huisman et al[218]	Not stated	Not stated	Not stated
Isaacs et al[219]	Not stated	Not stated	Not stated
Sutcliffe et al188	Not stated	Not stated	Not stated
Wood et al189	Not stated	Not stated	Not stated
Kim-Cohen et al[221]	Not stated	Not stated	Not stated
Kravariti et al[223]	Not stated	Not stated	Not stated
Croll et al[224]	Not stated	✓ Yes -definitely	Not stated
Kuntsi et al[225]	Not stated	✓ Yes -definitely	Not stated
Kyte et al[226]	Not stated	Not stated	Not stated
Magiati et al[228]	Not stated	✓ Yes -definitely	Not stated
Mehta et al[229]	Not stated	Not stated	Not stated
Milner et al[230]	Not stated	Not stated	Not stated
Newbury et al[231]	Not stated	Not stated	Not stated
Mulligan et al[232]	Not stated	Not stated	Not stated
Munir et al[233]	Not stated	Not stated	Not stated
Nosarti et al[234]	Not stated	Not stated	Not stated
Park et al[235]	Not stated	Not stated	Not stated
Park et al[236]	Not stated	Not stated	Not stated
Shield et al[239]	Not stated	Not stated	Not stated
Stevenson et al[240]	Not stated	Not stated	Not stated
Wright et al[242]	Not stated	Not stated	Not stated
Astle et al[243]	Not stated	Not stated	Not stated
Barker et al[179]	Not stated	Not stated	Not stated
Brookes et al[181]	Not stated	Not stated	Not stated
Conti-Ramsden[182]	Not stated	Not stated	Not stated
Conti-Ramsden et al[183]	Not stated	Not stated	Not stated
de Vries et al[184]	Not stated	Not stated	Not stated
Hibbeln et al[186]	Not stated	Not stated	Not stated
Murray et al[185]	Not stated	Not stated	Not stated
Joinson et al[220]	Not stated	Not stated	Not stated
Camilleri et al[272]	✓ Yes -definitely	✓ Yes -definitely	n/a
Everitt et al[273]	✓ Yes -definitely	✓ Yes -definitely	n/a
Wan et al[274]	✓ Yes -definitely	✓ Yes -definitely	Not stated
Garg et al[275]	Not stated	✓ Yes -definitely	Not stated
Meador et al[276]	✓ Yes -definitely	✓ Yes -definitely	Not stated
Newbold et al[277]	✓ Yes - Implied	✓ Yes -definitely	n/a
Schmid et al[278]	✓ Yes -definitely	✓ Yes -definitely	Not stated
Humphrey et al[279]	Not stated	Not stated	Not stated

Author	Assessors trained	Assessors audited	Study adjusted for multiple assessors
McKean et al[280]	Not stated	Not stated	Not stated
Carney et al[281]	Not stated	Not stated	Not stated
Willatts et al[282]	Not stated	Not stated	Not stated
Stringaris et al[283]	Not stated	✓ Yes -definitely	Not stated
Ahuja et al[284]	✓ Yes -definitely	✓ Yes -definitely	Not stated
O'Keeffe et al[285]	Not stated	Not stated	Not stated
Azzopardi et al[286]	Not stated	Not stated	Not stated
Li et al[287]	✓ Yes -definitely	Not stated	Not stated
Hughes et al[288]	Not stated	Not stated	Not stated
Khandaker et al[289]	✓ Yes -definitely	✓ Yes -definitely	Not stated
Kothari et al[290]	Not stated	Not stated	Not stated
Price et al[291]	Not stated	Not stated	Not stated
Martinos et al[292]	✓ Yes - Implied	Not stated	n/a
Als et al[293]	✓ Yes -definitely	Not stated	Not stated
Gage et al[294]	✓ Yes - Implied	Not stated	Not stated
Talcott et al[295]	Not stated	Not stated	Not stated
Wojcik et al[296]	Not stated	Not stated	Not stated
Christakou et al[297]	Not stated	Not stated	Not stated
McGonigle-Chalmers et al[298]	Not stated	Not stated	n/a
Sinderberry et al[299]	Not stated	Not stated	Not stated
Gammer et al[300]	✓ Yes - Implied	Not stated	Not stated
Arichi et al[301]	Not stated	Not stated	Not stated
Johnston et al[302]	Not stated	Not stated	Not stated
Rose et al[303]	✓ Yes -definitely	Not stated	Not stated
Iao et al[304]	Not stated	Not stated	Not stated
Livingstone et al[305]	Not stated	Not stated	Not stated
Broadbent et al[306]	Not stated	Not stated	Not stated
Pellicano[307]	Not stated	Not stated	Not stated