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REVIEW

What is the level of evidence for the use of currently available technologies in facilitating the self-management of difficulties associated with ADHD in children and young people? A systematic review

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Abstract
A number of technologies to help self-manage attention deficit hyperactivity disorder (ADHD) in children and young people (YP) have been developed. This review will assess the level of evidence for the use of such technologies. The review was undertaken in accordance with the general principles recommended in the Preferred Reporting Items for Systematic Reviews and Meta-Analysis. 7545 studies were screened. Fourteen studies of technology that aim to self-manage difficulties associated with ADHD in children and YP were included. Primary outcome measures were measures that assessed difficulties related to ADHD. Databases searched were MEDLINE, Web of Science (Core collection), CINAHL, the Cochrane Library, ProQuest ASSIA, PsycINFO and Scopus. The methodological quality of the studies was assessed. This review highlights the potential for the use of technology in paediatric ADHD management. However, it also demonstrates that current research lacks robustness; using small sample sizes, non-validated outcome measures and little psychoeducation component. Future research is required to investigate the value of technology in supporting children and YP with ADHD and a focus psychoeducation is needed.

Keywords Technology · Intervention · ADHD · Psychoeducation

Abbreviations

ADHD	Attention deficit hyperactivity disorder
ADHD-RS	ADHD Rating Scale
AVL	ADHD vragen lijst
BRIEF	Behaviour rating inventory of executive function
CBTT	Corsi block tapping task
CPT	Conners continuous performance test
CRoB	Cochrane risk of bias
DBDRS	Disruptive Behaviour Disorder Rating Scale
D-KEFS	Delis–Kaplan function system
HSQ	Home situations questionnaire
IATQ	It is about time questionnaire
ITT	Intention to treat
MABC-2-NL	Movement assessment battery for children
MCID	Minimally clinically important difference
MeSH	Medical subject headings
SDQ	Strengths and difficulties questionnaire
SPRSQ-C	Sensitivity to punishment and sensitivity to reward questionnaire for children
SRRS	Social skills rating system
TMT	Trail making test
TMQ	Time management questionnaire
RCT	Randomised controlled trial
SAST	South Australian spelling test
QbTest	Quantifying behaviour test
WAIS-RNI	Weschler adult intelligence scale-revised as a neuropsychological instrument
WASI	Weschler abbreviated scale of intelligence
WISC-III	Weshler intelligence scale for children three
WPPSI-RN	Wechsler preschool and primary scale of intelligence revised
YP	Young people

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Introduction

Attention deficit hyperactivity disorder (ADHD) is a highly comorbid [1–3] neurodevelopmental disorder. It has a worldwide prevalence of 3–5% in school age children [4], 80–85% of these individuals continue to be effected by their ADHD into adolescence [5–8] and 60% into adulthood [9].

Due to the symptoms and complexity of the condition, there are a number of important long-term difficulties associated with ADHD. These include low academic attainment [10, 11], which can persist into adulthood [12], poor executive functioning [13], poor social relationships, strained parent/child/sibling relationships [14] and problems with social interactions with peers [15]. This results in poorer quality of life and self-esteem in children and YP with ADHD [16, 17].

Children and YP with ADHD are reliant on clinicians and parents to help them to manage their condition. However, as they transit into adulthood, the support is not as readily available or indeed wanted by the individual [18]. It is, therefore, imperative that children and YP learn to self-manage their condition and indeed be educated about their condition and how to manage it [19–23]. Individuals with ADHD often experience crises and access to their usual services may not be immediately available. However, the increasing sophistication and usage of technology may provide valuable resources to facilitate the self-management of ADHD for children and YP.

Over recent years, technological advances have meant that technology is more widely available and has become more popular and integrated into many lives. Society is also better connected with an estimated 46% of the worldwide population having an internet connection compared with 1% in 1995 [24]. As a result of this, a number of attempts have been made to harness technology to help manage ADHD in children and YP such as eye tracking [25], brain computer interface [26, 27] and a computerised test that quantifies ADHD core symptoms; the QbTest [28]. Technology has also been used for cognitive training in children and YP with ADHD [29]. However, these technologies are reliant on an administrator or a therapist. Other technologies have been developed to self-manage ADHD-related difficulties in children and YP that can be used independently of a therapist which, therefore, reduces the reliance on services. These include a handheld organisation device [30], a device to self-monitor ADHD symptoms [31], computer software to improve reading speed [32], and computer games that focus on mathematical ability [33] and the promotion of behavioural learning and organisation [34]. Although these studies report that technology has the potential to self-manage ADHD-related difficulties in children and YP, little is known about the level of evidence for these technologies. Therefore, this review will assess the level of evidence for currently available technologies for self-managing ADHD and related difficulties in children and YP.

Methods

The review protocol was registered with PROSPERO (CRD42017057715). The review was undertaken in accordance with the general principles recommended in the Preferred Reporting Items for Systematic Reviews and Meta-Analysis [35].

Search methods

The following databases were searched in February 2017 from the last 5 years: MEDLINE, Web of Science (Core collection), CINAHL, the Cochrane Library, ProQuest ASSIA, PsycINFO and Scopus. Medical Subject Headings (MeSH) keywords used were attention deficit disorder with hyperactivity, hyperkinesis, attention deficit and disruptive behaviour disorders, conduct disorder, child behaviour disorders, disruptive impulse control and conduct disorders, adolescent, young adult, educational technology, technology, self-help devices, video games, internet, software, social media, mobile applications, self care and social support. Text terms used were attention deficit and disruptive behaviour disorders, attention deficit hyperactivity disorder, ADHD, ADDH, ADHS, hkd, attention, behaviour, dysfunctional, disorder, disrupt, defiant, impulsive, inattentive, inattention, hyperkinesis, damage, hyperactive, conduct, child, boy, girl, young person, YP, young people, adolescent, teen, youth, technology, assistive technology, self-help devices, game, website, download, forum, email, mobile app, condition management, manage, self-manage, support and support network. Terms were combined using Boolean logic ("AND", "OR"). MeSH is specific recognised terms used for the purpose of identifying journal articles and books in electronic databases. Free text terms and synonyms are specific words that the search strategy looks for in the title and abstract.

A copy of the MEDLINE search strategy is presented in Appendix 1. Electronic citations were downloaded to Endnote software. The inclusion criteria are described in Table 1. Studies included in this review were from 2014 to 2016.

Due to the infancy of this research topic, any study design was accepted as appropriate to answer the research question. The research question is "What is the level of evidence that current technology that aims to self-manage difficulties associated with ADHD in children and young people is helpful?" The primary outcome measures (see Table 2) of this review are measures that assess ADHD related difficulties.

Table 1 Inclusion and exclusion criteria for this review

Inclusion criteria	Exclusion criteria
English language articles	Studies where intervention is not clearly defined
Studies recruiting individuals under the age of 18 years	Studies including individuals over the age of 18 years
Evaluating technologies that can be used independently of a therapist	Non-interventional studies
Participants reported to have ADHD diagnosis	Interventions that are led by anybody other than the child/YP with ADHD (e.g. clinician led interventions)
	Participants without reported ADHD diagnosis (e.g. parent or teacher reported)
Validated outcome measures assessing ADHD-related difficulties	Outcome measures that do not assess ADHD-related difficulties or are not validated

ADHD attention deficit hyperactivity disorder

Table 2 List of included outcome measures

Observational checklist for observations and recording behaviours	Conners parent scale (brief version)	Corsi Block Tapping Task (CBTT)
Chart to track each students appropriate behaviour	Connors teacher rating scale	Digit span subtest from the Weschler Intelligence Scale for Children (WISC-III)
Guided reading packet	5 subtests from the Movement Assessment Battery for Children (MABC-2-NL)	Disruptive Behaviour Disorders Rating Scale (DBDRS; parent and teacher versions)
X 2 outcome measures—multiple choice, fill in the blanks and short answer response	Behaviour Rating Inventory of Executive Function (BRIEF): plan/organise	Sensitivity to punishment and sensitivity to reward questionnaire for children (SPRSQ-C)
Total time to complete reading	BRIEF: working memory subscale—parent	Paediatric quality of life inventory (PedsQL; parent and child versions)
Sustained attention dots task version 02 k	Shape school	Counting span task
Calculating time for distractions	BRIEF—inhibit	Connors Continuous Performance Test (CPT II)
Time calculation	BRIEF—shift	WISC III
Barkley School Situations Questionnaire	BRIEF—emotional	Social Skills Rating Scale (SRRS) self-control subscale
Go/no-go task (not QbTest)	BRIEF—control initiate	SRRS total
Time management questionnaire—parent and teacher completion	BRIEF—organisation of materials	ADHD VragenLijst (AVL)
It's About time Questionnaire (IATQ)—parent version	BRIEF—monitor	SSRS—teacher version
Self efficacy questionnaire	BRIEF—metacognition index	Stop task
Knox cubes LDT	Weshler Preschool and Primary Scale of Intelligence Revised translated in Dutch (WPPSI-R NL)	ADHD Rating Scale 1 (ADHD-RS-1)
Action detector	Subscale of Cooperation of the SRRS (parent version)	Stroop (and day/night version)
Duration of arbitrary standing	SRRS: subscales Responsibility	The home situations questionnaire (HSQ)
Disruptive Behaviour Disorder Rating Scale (DBDRS)	SRRS: assertiveness subscale	Raven coloured progressive matrices (full and shortened version)
Improvement index during training	Three subtests in Mandarin Literacy Assessment	ADHD Rating Scale (ARS-IV)
Strengths and Difficulties Questionnaire (SDQ)	Trail Making Test (TMT) of the Delis-Kaplan Function System (D-KEFS)	Weshler Abbreviated Scale of Intelligence (WASI)
South Australian Spelling Test (SAST)		

Quality Assessment

Methodological quality of included studies was assessed using the Cochrane Risk of Bias tool (CRoB) [36] for RCT designs and the Downs and Black Instrument [37] for non-RCT designs. This CRoB tool addresses specific domains, namely, sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome

assessment, incomplete outcome data, and selective outcome reporting. The Downs and Black Instrument provides an individual score for each study with a maximum score of 32 [37] and assesses the way in which the studies report their findings, external validity, internal validity bias and selection bias.

Data extraction

Retrieved titles, abstracts, and/or papers were screened independently by 2 review authors (LP, JP) to identify studies that met the inclusion criteria. Disagreements were resolved between reviewers through discussion. A standardised form was used for data extraction using Microsoft Excel. Details of the study characteristics, including participants, the intervention, and comparator (where applicable) were recorded. Data extraction was carried out by reviewer LP and checked for accuracy by reviewer JP.

Outcome measurement assessment

It is vital that when undertaking a systematic review, the quality of the outcome measures used in each of the included studies is assessed. This is to ensure the validity and reliability of their results. To complete the outcome measure quality assessment, where possible, three domains should be considered for each outcome measure [38], (1) whether the psychometric properties of the scale have been assessed previously [39], (2) whether the clinimetric properties of the outcome measure have been thought through [40–44], specifically the Minimally Clinically Important Difference (MCID) [43], and (3) whether the design and analysis of the outcome measure satisfies the requirements of measurement theory [45–47]. We identified all outcome measures ($N = 58$) used across the 14 studies and reviewed each of them individually to assess whether they fulfilled the first domain described above. The MCID was not assessed for the included outcome measures and was, therefore, not assessed. The 58 included outcome measures are listed in Table 2.

Literature for each outcome measure, where applicable, was reviewed. We then examined each outcome measure to ascertain how the data were scored, collected and analysed within the results section of each study.

In line with the literature, all 58 outcome measures included were measures of difficulties related to ADHD.

Data synthesis

We have presented a narrative overview of the included studies with supporting evidence tables and text. A meta-analysis was not undertaken.

Appraisal of evidence

The results of the search varied from case studies to Randomised Controlled Trials (RCTs). The studies identified were appraised using the levels of evidence [48] to locate the best available evidence that involves the application of systematic, robust, transparent and explicit methodology [49]. The grading system (see Table 3) was created to highlight that varying study designs and methodologies are at risk of bias in their results. This is crucial as the study design may affect the validity and reliability of results due to the research method used. For example, when evaluating the effectiveness of an intervention, it is often considered that RCT evidence is the "gold standard", the most reliable form of evidence due to the measures they take to reduce the influence confounding variables could potentially have on the results [50].

Table 3 Levels of evidence outlined by Weiss et al. [48]

Level of evidence	Non-empirical	Group research	Outcome research	Single participant research
I	–	Randomised controlled trial	–	N-or-1 randomised controlled trial
II	–	Non-randomised control trial Prospective cohort study with concurrent control group	Analytic survey	ABABA design Alternating treatments. Multiple baseline across participants
III	–	Case–control study. Cohort study with historical control group	–	ABA design
IV		Before and after case series without control group	–	AB design
V	Descriptive case series Anecdotes Expert opinion Theories Common sense		–	–

Results

Search results

The electronic searches identified 7391 citations following de-duplication, including 9 additional citations that were identified through reference searches/other sources. We excluded 7331 citations at the title and abstract stages as they did not fit the inclusion criteria. We then obtained 60 citations as full-text articles. Of these, 50 were excluded at the full-text stage; details of these excluded studies with the reason for exclusion are shown in Appendix 2. 14 studies reported across 14 publications were included in the review (see Fig. 1). Four of these publications were obtained from a recent meta analysis [29], which examined the effects of cognitive training on ADHD symptoms, neuropsychological deficits, and academic skills in children and YP with ADHD [51–54].

Quality assessment

Full details from the Cochrane risk of bias assessment are presented in Appendix 3. A summary of the RCT risk of bias assessment is presented in Table 4, non-RCT risk assessment

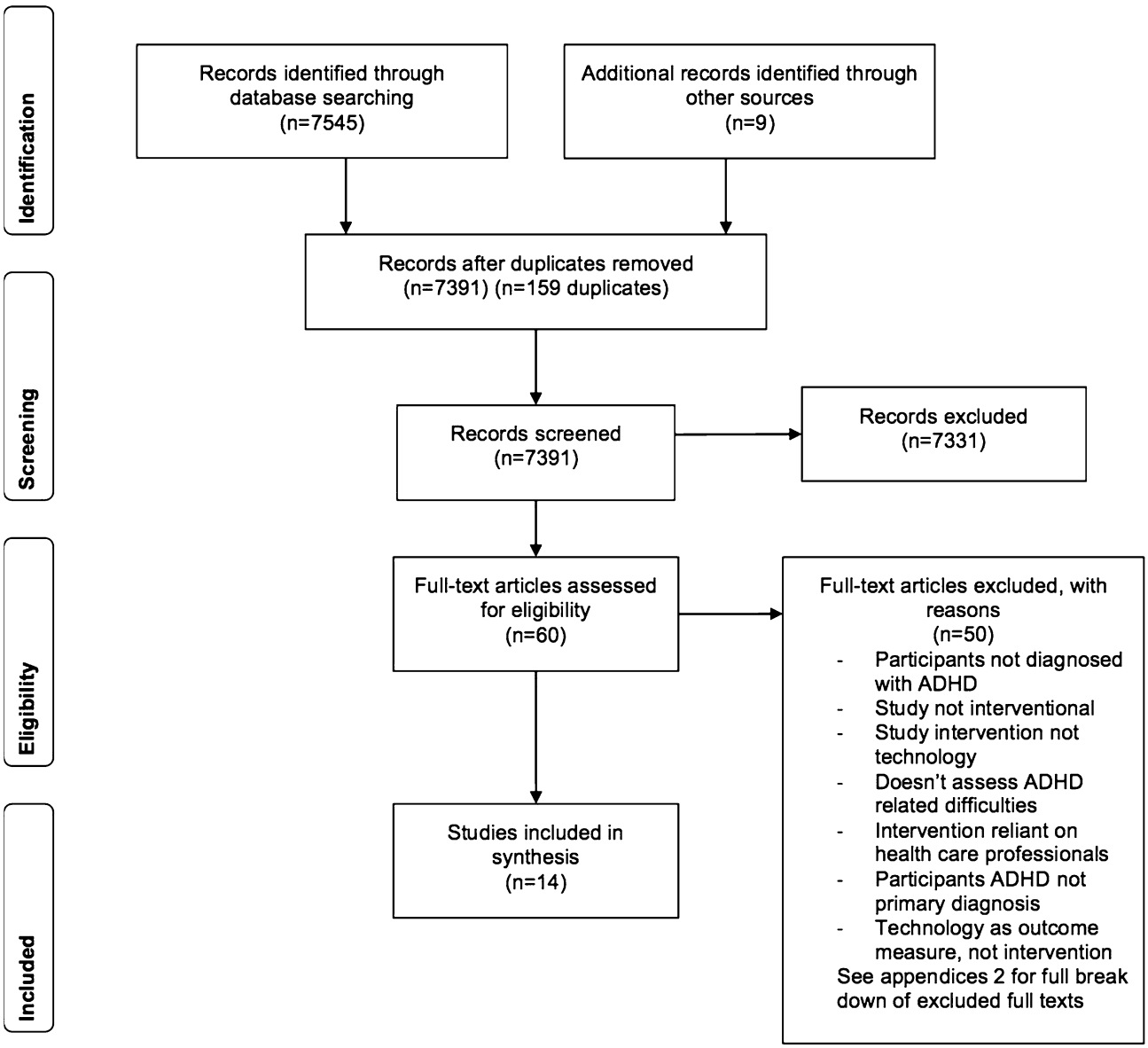

Fig. 1 Studies included in this review

Table 4 RCT risk of bias summary

Study	Random Sequence Generation	Allocation Concealment	Blinding of Participants and Personnel	Blinding of Outcome Assessment	Incomplete Outcome Data	Selective Reporting
Bul, 2016 [34]	Low risk	Low risk	High Risk	High Risk	High Risk	Low risk
Van der Oord, 2014 [57]	Low risk	Unclear	Unclear	Unclear	Low risk	Low risk
Dovis, 2015 [55]	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Weerdemeester, 2016 [56]	Low risk	Low risk	High Risk	Low risk	Low risk	Low risk
Van Dongen-Boomsma [51]	Unclear	Low risk	Low risk	Low risk	Low risk	Low risk
Egeland, 2013 [52]	Unclear	Low risk	High risk	High risk	Low risk	Low risk
Klingberg, 2005 [54]	Unclear	Unclear	Low risk	Low risk	High risk	Low risk
Johnstone, 2012 [53]	Unclear	Unclear	Unclear	Unclear	Unclear	Low risk

in Table 5 and a summary of the outcome measurement quality assessment can be found in Appendix 5.

One of the eight included RCTs, one was considered to be at overall high risk of bias [34], five RCTs were judged as being at overall low risk [51, 52, 54, 55, 56] and two RCTs were considered to be at overall unclear risk of bias [53, 57]. All included RCTs were considered to be at a low risk of bias for selective reporting [34, 51–57].

Non-RCT study designs were assessed using the Downs and Black Scale, as they were mainly exploratory interventional studies. Overall, the non-RCT studies obtained low scores on items covering external and internal validity, selection bias and statistical power. Studies obtained higher scores for the items covering reporting of results and study procedures. The maximum total score that could be obtained is 32. Of the six included non-RCT studies in this review, the lowest score was 6 [58] and the highest score was 11 [59, 60].

Quality assessment of measurement scales

Ten of the fourteen included studies [34, 51–58, 63] used ordinal scales of measurement all with established psychometric properties. Twelve of the included studies [34, 51, 53–62] used scales of measurement that did not have established psychometric properties. Four of the fourteen studies [58–60, 63] did not perform any formal statistical analysis. The sample size for these four studies ranged from one to eight. Five of the fourteen studies [34, 52, 53, 56, 57] aggregated data used with ordinal scales, which may put findings at risk. Further details of the outcome measurement quality assessment can be found in Appendix 5. Description of the studies can be found in Table 6.

Discussion

This review set out to answer the question "What is the level of evidence that current technology that aims to self-manage difficulties associated with ADHD in children and young people is helpful?" The review found that the evidence demonstrates that technology shows promise in self-managing difficulties related to ADHD in children and YP. However, this claim is based on evidence that often consists of small sample sizes, use a wide variety of outcome measures (many of which are not validated) and provide little support for the importance of the role of psychoeducation in children and YP with ADHD that has been so widely reported and encouraged elsewhere [19–23, 64]. For example, the European Guidelines suggest psychoeducation for parent/carer and child with ADHD as a first step to treatment [23]. One systematic review even stated that psychoeducation for YP with ADHD and their families could provide an expert understanding of their condition could lead to more positive individual choices [20].

Of the fourteen included studies in this review, the interventions assessed include two tablet devices [59, 60] two mobile applications [58, 62], the use of a Wii remote control [61], computer software [51, 54] and computer games [34, 52, 53, 55–57, 63]. Following exclusions, outcome measure assessment (Appendix 5) and quality assessment of the fourteen included studies was conducted (appendices 3 and 4).

Only four of the sixteen papers included in the Cortese et al. [29] meta analysis were included in this review [51–54] and one additional paper resulted from our search strategy before the Cortese review was screened for studies to include in this review [57]. Two of the unincluded papers presented in this meta analysis [29] did not report technological interventions [65, 66], one did not use validated outcome measures of ADHD-related difficulties [67], four reported

Table 5 non-RCT risk of bias summary

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	Total
Bamford, 2016 [59]	1	1	1	1	0, N/A, participants in one group	2	0, N/A	0	0, N/A	0, no formal stats reported	0	0	1	0	0	0	1	0, no formal stats reported	1	0	1	1	0, N/A, not RCT	0, N/A, not RCT	0 UTD, no confounds reported	0, N/A	0	11
Pinna, 2015 [60]	1	1	1	1	0, N/A, participants in one group	2	0, N/A	0	0, N/A	0, no formal stats reported	0	0	1	0	0	0	1	0, no formal stats reported	1	0	1	1	0, N/A, not RCT	0, N/A, not RCT	0 UTD, no confounds reported	0, N/A	0	11
Ruiz-Manrique,2014 [58]	0	1	1	0	0, N/A, participants in one group	1	0, N/A	0	0, N/A	0, no formal stats reported	0	0	0 UTD	0	0	0	0, N/A	0, no formal stats reported	1	1	0 N/A	1	0, N/A, not RCT	0, N/A, not RCT	0 UTD, no confounds reported	0, N/A	0	6
Shih, 2014 [61]	0	1	1	1	0, N/A, participants in one group	2	0, N/A	0	0, N/A	2	0	0	0 UTD	0	0	0	0	0	1	0	0 UTD	1	0, N/A, not RCT	0, N/A, not RCT	0 UTD, no confounds reported	0, N/A	0	9
Lin, 2016 [62]	1	1	1	0	0, N/A, participants in one group	2	0, N/A	0	0, N/A	2	0	0	0 UTD	0	0	0	1	0	0 UTD	0	0 UTD	1	0, N/A, not RCT	0, N/A, not RCT	0 UTD, no confounds reported	0, N/A	0	9
Rijo, 2015 [63]	0	1	1	1	0	2	0, N/A	0	0, N/A	0, no formal stats reported	0	0	1	0	0	0	1	0, no formal stats reported	0 UTD	1	0	1	0, N/A, not RCT	0, N/A, not RCT	0 UTD, no confounds reported	0, N/A	0	9

*Item modified (see Appendix 4 for further details)

Table 6 Summary of study, participant and intervention characteristics and results

Authors, year, country, study design, level of evidence	Number recruited (*N*), final follow-up (*n*) overall and between groups	Gender, mean age (years), how ADHD diagnosis confirmed	Intervention and length/frequency/groups in study	Outcome measures used and ADHD-related difficulty domain assessed*	ADHD-related difficulty results and reported *p* values
Bamford, 2016, USA, single subject design (ABAB), level III [59]	$N = 4$	2 males, 2 females, 16.5, medical diagnosis ($N = 4$)	iPad choice works app, 20 min (baseline observation), use app for 8 days, single participant group	Guided reading packet, multiple choice, observation checklist, education*	A trend towards improvements in on task behaviour was reported when participants used the iPad
Pinna, 2015, USA, case series, level IV [60]	$N = 9$	7 males, 2 females, 13, diagnosed by psychiatrist, psychologist or physician	Tablet-based reading app designed to help reading, answer questions about the text and record the answer. Participants read at same time on 2 separate days, day 1 reading a book, day 2 reading text on app, single participant group	Total time to complete reading, calculating time for distractions, time calculation, ADHD symptoms*	No significant differences were found in student's ability to recall information from a story were observed when they read from the application or a book
Ruiz-Manrique et al., 2016, Spain, case study, level V [58]	$N = 1$	Male, 10 years, DSM V criteria	App "ADHD Trainer", every day at the same time, no more than 4 h daily for first month (average 1 h per day), at least 10 min per day for following month, single participant group	Conners parent Scale (brief version), Connors teacher rating scale, Barkley School Situations Questionnaire, ADHD symptoms*	ADHD symptoms improved following training. BSSQ was 70 pre and 66 post training. Conners scores were 19 for teachers and 20 for parents pre training, 15 for teachers and 16 for parents post training. Authors report that findings demonstrate that "cognitive computerised training" may improve some ADHD cognitive symptoms
Weerdemeester et al., 2016, The Netherlands, 2 arm feasibility RCT, adventurous dreaming highflying dragon computer game (ADHD group), computer game without ADHD focussed training components (control group), level II [56]	$N(n) = 73(66)$, intervention; 37(32), control; 36(34)	58 males, 15 females, 9, formal diagnosis ($N = 39$), elevated symptoms (no diagnosis or other diagnosis; ($N = 26$), comorbid disorder ($N = 8$)	Computer games: "Adventurous Dreaming Highflying Dragon" (intervention), comparable intervention without ADHD focussed training components (control), 6 15-min sessions over 3 weeks, intervention and control group	ADHD VragenLijst (AVL), Go/no-go task, MABC-2-NL, ADHD symptoms* and motor skills*	Total and hyperactivity sections of AVL and the Go/No-go outcomes demonstrated improvements ($p \leq 0.05$). The impulsivity section of the AVL and the fine motor skills also showed improvements ($p \leq 0.10$). Teacher-rated ADHD symptoms improved in the intervention compared to control group ($p \leq 0.05$)

Table 6 (continued)

Authors, year, country, study design, level of evidence	Number recruited (*N*), final follow-up (*n*) overall and between groups	Gender, mean age (years), how ADHD diagnosis confirmed	Intervention and length/frequency/groups in study	Outcome measures used and ADHD-related difficulty domain assessed*	ADHD-related difficulty results and reported *p* values
Bul et al., 2016, The Netherlands, RCT crossover trial, serious game intervention (intervention), treatment as usual (control), level 1 [34]	*N*(*n*) = 170(139), intervention; 88(68), control; 82(71)	137 males, 33 females, 9, DSM IV criteria	Serious game intervention (programmed so can not play more than 65 min in 24-h period) called "Plan-It Commander", or treatment as usual, 10 weeks, intervention and control crossover design	Time management questionnaire—parent and teacher completion, subscale Plan/Organise and working memory of BRIEF, Subscale of cooperation, responsibility, assertiveness, self control and total SRRS of SRRS, IATQ, SRRS teacher version, self efficacy questionnaire, social skills*, self efficacy* and executive function*	Group 1 participants significantly improved time management skills compared to group 2 (parent reported; $p = .02$). Parents and teachers reported total social skills improved within groups effects on total social skills and teacher reported planning/organising skills were non-significant between groups. Group 1 positive effects were maintained and improved in last 10 weeks of study
Shih et al., 2014, Taiwan, before and after case series, level IV [61]	*N* = 2	2 males, 8.5, diagnosed, details not reported	Wii remote controller and control system, used to detect activity in students and giving them reminders when they are standing (rather than sitting) in the classroom, 40-min sessions, 3–5 times per week, single participant group	Action detector and duration of arbitrary standing, ADHD symptoms*	Both participants improved hyperactive behaviour during intervention phase ($p < 0.01$). Effects maintained at maintenance phase (1 week later)
van der Oord et al., 2014, The Netherlands, 2 arm RCT, Executive function training (intervention) or wait list (control), level I [57]	*N*(*n*) = 43(40), treatment 21(18), wait list 22(22).	33 males, 7 females, 9.75, DSM IV diagnosis (*N* = 77)	Computer game (macintosh computer installed in participant's homes), EF training group consisted of 25 40 min over 5 weeks. Sessions covered inhibition, cognitive flexibility and working memory, intervention and wait-list conditions	All subscales of BRIEF, DBDRS, ADHD symptoms*, executive function*	Participants in the EF training showed improvements compared to those in wait-list condition on parent rated EF and ADHD behaviour in total sample and subsample (those treated with methylphenidate). Effects maintained at follow-up. Between group differences suggested for ODD subscale of DBDRS

Table 6 (continued)

Authors, year, country, study design, level of evidence	Number recruited (*N*), final follow-up (*n*) overall and between groups	Gender, mean age (years), how ADHD diagnosis confirmed	Intervention and length/frequency/groups in study	Outcome measures used and ADHD-related difficulty domain assessed*	ADHD-related difficulty results and reported *p* values
Dovis et al., 2015, The Netherlands, 4 arm RCT, full active condition (visuospatial WM, inhibition and cognitive flexibility trained), partially active condition (inhibition and cognitive flexibility trained), WM training task presented in placebo mode and a full placebo condition, level I [55]	*N*(*n*) = 89(57), full active training 31(20), partially active training 28(21), placebo training 30(16)	71 males, 18 females, 10, DSM IV diagnosis	Computer game "Braingame Brian", 5 weeks, weekly phone calls from research team, four groups: "full active" (visuospatial WM, inhibition, cognitive flexibility training), "partially active" (inhibition and cognitive flexibility), WM training task presented in placebo mode and full placebo condition	Improvement index during training, Stop task Stroop, CBTT, WISC-III, TMT of D-KFES, Raven, DBDRS, BRIEF, SPRSQ-C, PedsQL, Home situations Questionnaire, executive function*, ADHD symptoms*, QoL*, social skills*	Improvements were observed in visual spatial STM and WM, inhibitory performance and interference control
Lin et al., 2016, Taiwan, single case (ABA), level III [62]	*N* = 2	2 males, 11, diagnosed, details not reported	App, Mobile Augmented Reality (MAR), data collected over 3 months, single participant group	Three subtests in Mandarin Literacy Assessment (MLA), education*	MLA scores increased during intervention and maintenance phases($p < 0.05$)
Rijo et al., 2015, Portugal, before and after case series, level III [63]	Study 1: *N* = 8, study 2: *N* = 12 (*N* = 6 ADHD, *N* = 6 not ADHD)	Study 1: 2 males, 2 females, 7, not diagnosed. Study 2:gender not reported, 7, *N* = 6 diagnosed, details not given	Computer serious game involving a treasure hunt find things like letters and words, 3 months, daily use monitored by the research team, two studies, single participant groups in each	CPT II, WISC III, ADHD symptoms*, executive function*	A trend towards improved CPT II and WISC III scores post intervention was reported
Van Dongen-Boomsma et al., 2014, The Netherlands, randomised placebo control trial, level I [51]	*N*(*n*) = 51(47), intervention; 27(26), control 24(21)	34 males, 17 females, intervention; 6.5 ± 0.6, control; 6.6 ± 0.7, DSM IV criteria	CogMed Working Memory Training (CMWT; computer software). 25 sessions of 15 min, 5 days a week, sessions. Both conditions included 7 visuo spatial working memory tasks. In intervention group, software adjusted task difficulty based on child's performance. Control group same as intervention, exec items to memorise did not exceed starting level, intervention and control	ADHD-RS-1, BRIEF (parent and teacher Dutch versions), BRIEF-P, Adapted didgit span from WISC-III, Knox cubes LDT, Sentences from WPPSI-RN, Shortened Ravens progressive matricies, Day night stroop task, Sustained attention dots task version 02 k, Shaoe school	Does not provide evidence in favour of CMWT. Significant improvement of active condition found on verbal working memory task ($p = .041$; adapted Digit Span WISC-III..No significant treatment effect on any other outcome measurements. No significant differences found in ADHD-RS and Behavior Rating Inventory of Executive Function

Table 6 (continued)

Authors, year, country, study design, level of evidence	Number recruited (*N*), final follow-up (*n*) overall and between groups	Gender, mean age (years), how ADHD diagnosis confirmed	Intervention and length/frequency/groups in study	Outcome measures used and ADHD-related difficulty domain assessed*	ADHD-related difficulty results and reported *p* values
Egeland et al., 2013, Norway, RCT, level I [52]	*N*(*n*) = 75(67), intervention 38(33), control 37(34)	49 males, 18 females, 10.4, ICD-10 criteria	CogMed roboMemo program performed daily at school for 5-7 weeks, 30–45 min in length, consists of 13 adaptice exercises, difficulty level altered based on child's performance. Tasks taxed working memory capacity, these included tasks such as letter and digit span tasks. Two groups; intervention and control	ARS-IV ADHD rating scale, SDQ, BRIEF metacognition index and general executive composite	Significant training effect in psychomotor speed, but not to any other neuropsychological measures. No training induced changes in symptom rating scales at home or school
Klingberg et al., 2005, Sweden, double blind RCT, Level I [54]	*N*(*n*) = 53(46), intervention 27(20), control 26(24)	36 males, 8 females, intervention 9.8, control 9.9, reports ADHD diagnosis confirmed	Working memory tasks in a computer program "RoboMemo® Cogmed Cognitive Medical systems AB", provided on a CD, used by child on personal computer at home or school. Included visuo spatial working memory tasks. Children performed 90 trials on each day, around 40 min per day, difficulty level adjusted based on child's performance	WAIS-RNR, Digit span from WISC III, Stroop interference, Raven's coloured progressive matrices, Connors for parents and teachers	Significant effects for verbal WM; Digit span $p = .01$ post intervention/$p = .03$ at follow-up, Stroop (accuracy) $p = .004$ post intervention/$p = .44$ follow-up response inhibition, and complex reason in measures. Parent ratings showed significant reduction insymptoms of inattention (post intervention: $p = .002$; follow-up: $p = .04$) and hyperactivity/impulsivity (post intervention/follow-up: $p = .03$), both post intervention and at follow-up
Johnstone et al., 2012, Australia, randomised waitlist control, Level I [53]	*N*(*n*) 151(128), waitlist (WL) ADHD group $n = 20$, Software (SW) ADHD group $n = 22$, software with attention monitoring (SWAM) ADHD group $n = 18$, non ADHD WL $n = 25$, non ADHD SW group $n = 23$, non ADHD SWAM group $n = 20$. Drop out rate not reported therefore post training assessment n not available	96 males, 55 females, ADHD WL 19 male, 1 female, SW ADHD group 19 males, 3 females, SWAM ADHD group 16 males, 2 females, non ADHD WL group 15 males, 10 females, non ADHD SW group 15 males, 8 females, non ADHD SW + AM group 12 males, 8 females	Three conditions; waitlist, working memory and inhibitory control with attention monitoring or working memory and inhibitory control without attention monitoring. Reported as ADHD diagnosis confirmed	WASI, South Australian Selling Test, Counting span task	Non-significant post training improvements in spatial working memory ($p = .066$), ignoring distracting stimuli, and sustained attention reported for children with ADHD and without. Improvements for both groups maintain 6-weeks after training. Results suggest combined training can result in improved behavioural control for children with and without ADHD

technological interventions that were not for independent use [68–71], two reported on participants who did not have a primary diagnosis of ADHD [72, 73] and two of the studies did not report including participants who had an official clinical diagnosis of ADHD [74, 75]. One of these papers reported participants who had a parent-reported ADHD diagnosis [75]. Papers included in this review all report on participants who have obtained a formal ADHD diagnosis. This is crucial to ensure that comparisons can be made across studies. Parent-reported diagnoses may not be as reliable as clinically reported diagnoses and therefore do not enable comparisons to be made and therefore the results from such studies should be interpreted with caution.

The interventions used in ten [34, 51–57, 61, 62] of the fourteen included studies identified statistically significant results for some, not all, primary outcome measures included in this review. Statistically significant improvements included improved ADHD symptoms [54, 56, 57, 61], social skills [34], executive functioning [51, 52, 54, 55, 57] and educational outcomes [62]. Statistical significance was not observed for the quality of life [55] or self-efficacy [34] measures which interestingly, only featured in two of the included RCTs [34, 55]. Although a trend towards improved symptoms [58, 61] and executive functioning [63] was observed in three of the included studies [58, 61, 63], no formal statistical analysis was undertaken and the sample sizes were small ranging from one to eight participants. Therefore, these findings should be interpreted with caution.

As described fully in the quality assessment, one of the eight included RCTs were considered to be at overall high risk of bias [34], two were considered as having an unclear rick of bias [53, 57] and five were considered as having a low risk of bias [51, 52, 54, 55, 56]. This does not mean that interventions were not successful in improving ADHD-related difficulties. A number of conclusions could be drawn from this including the difficulty of blinding participants to an intervention as it is often impossible to conceal which arm participants are randomised to. It is also difficult to stop a potentially impulsive and hyperactive population to withhold their randomization allocation to an outcome measure assessor. Overall, the included non-RCTs obtained low scores on the Downs and Black scale. Out of a maximum score of 32, two studies scored eleven [59, 60], three scored nine [61–63] and one obtained a score of six [58]. A number of conclusions could be drawn from this including low sample sizes and the non-RCT nature of the studies (thus obtaining low scores on items that assess whether or not participants and research staff are blinded).

Of the fourteen included studies in this review, five [34, 52, 53, 56, 57] aggregated data with ordinal scales, four used no formal statistical analysis [58–60, 63] and two carried out statistical analysis when their sample sizes only consisted of two participants each [61, 62]. Clinimetric properties were not described for any of the primary outcome measures of this review. The lack of statistical significance across a number of outcome measures in this review could be a result of lack of statistical power due to small sample sizes and the inability to ascertain a clinically meaningful result.

The results from this systematic review should be generalised to a wider population of children and YP with ADHD with caution due to the low recruitment figures for five of included studies where n ranged from one to twelve [58–62] and only two of the included RCTs had a sample size of more than one hundred [34, 53]. Observations of the lack statistical significance should also be interpreted with caution, given the level of evidence provided and the methodological quality of the existing evidence base.

This review included a small number of papers including 1040 participants overall with 170 being from one study alone [34]. Six of the selected studies recruited fewer than 20 participants [51, 58, 61–63]. This could be for a number of reasons. It may have been difficult to engage with and recruit YP with ADHD to a research study, although this has not been our personal experience.

Additionally, ADHD severity and the presence of comorbidity can affect the level of impairment experienced by the individual, which can affect the way in which they respond to interventions. The included studies did not report the severity of the ADHD in their participants. However, one study [52] reported that their participants were participants were diagnosed with hyperkinetic disorder according to the International Statistical Classification of Diseases and Related Health Problems 10 (ICD-10) [76]. This diagnosis would have been based on narrower criteria than the DSV-IV as in the ICD-10 ADHD is diagnosed based on a minimum number of symptoms in all three dimensions (inattention, impulsivity and hyperactivity) [76] whereas the DSM-IV requires a minimum number of symptoms in one dimension [77]. This means that it is difficult to inter a significant improvement of ADHD-related difficulties.

There are a number of reasons evaluating a complex intervention with this population could remain challenging. For example, no ADHD diagnosis is the same. ADHD is a highly comorbid condition with a large number of potential-related difficulties. The extent to which each individual is impaired by their ADHD symptoms and related difficulties are also highly variable. In this review, four studies excluded participants who had specific comorbid diagnosis [51–53, 55]; one study excluded participants with autism spectrum disorder and conduct disorder [55], one study excluded participants diagnosed with pervasive developmental disorders, Tourette's disorder and those who show evidence of bipolar disorder and conduct disorder [52]. One study excluded those diagnosed with pervasive developmental disorder [51] and another study excluded those with any "clinically significant comorbid condition" [53]. These findings should

be interpreted with caution as at least 65% of children and YP diagnosed with ADHD have a comorbid condition [1] therefore these participant groups are not representative of the wider ADHD population. These factors coupled with evaluating an intervention make it very difficult to ascertain a clinically significant improvement in this population following the use of an investigative intervention. It also means that it is difficult to control each arm of an RCT study design. It has therefore been suggested [78] that the integration of realist evaluation within an RCT design may be more appropriate for evidence-based medicine whereby "statistically significant benefits may be marginal in clinical practice" [79].

The results of the included studies were not combined for a meta-analysis due to the variety of the types and quality of data collected for the primary outcome measures. It would also be difficult to compare primary outcomes across the included studies accurately as there was a wide variety of measures assessing ADHD-related difficulties used, many of which lacked validity as a measure of ADHD-related difficulties in children and YP.

Despite the wide variety of outcome measures included in this review, none of them assessed ADHD knowledge and understanding. To self-manage ADHD, the Chronic Illness Model [80] states that psychoeducation with a collaborative care model enhances health outcomes [64]. Similarly, the Health Belief Model states that people are more likely to seek treatment if they have knowledge and understanding of their condition [81, 82]. It is important that ADHD psychoeducation delivery is conveyed to the individual and their parents in a culturally appropriate manner, via a reputable website and written and updated by reputable experts [64]. It has been suggested that psychoeducaiton for parents and the YP with ADHD is the first step to treatment [23]. A systematic review has emphasised the value of psychoeducation for children and YP with ADHD can lead to an expert understanding of their condition and lead them to making more positive individual choices [20]. Public Heath England [19] and the Mental Health Taskforce's Five Year Forward View for Mental Health [22] states that early intervention avoids YP falling into crisis and expensive and longer-term interventions into adulthood. Therefore, it is vital that ADHD psychoeducation begins as early as possible following an ADHD diagnosis so that the YP can learn to accept and self-manage their condition in preparation for transition into adulthood.

Transition periods are particularly challenging for somebody diagnosed with ADHD and they present frequently throughout the course of a young person's life. For example YP move to secondary education, undertake regular exams, have to navigate through puberty, sometimes move house and many transfer adult ADHD services. The latter is particularly challenging due to the nature of child and adult ADHD services being very different and providing support in very different ways. Child services provide more in person support and may involve more frequent appointments than adult services. Therefore, a smooth transition between services is vital for a YP with ADHD to minimise disruption [83]. Despite this evidence, none of the included studies provided psychoeducation as part of their interventions.

Future research should focus on the development and co-collaboration of an evidence-based intervention that may focus on psychoeducation for this population. Due to the majority of the included interventions in this review taking the form of computer games, perhaps an ADHD technological intervention with a psychoeducation focus should take a different form such as a website. Evidence suggests that to engage with this population, technological interventions should be interactive [84, 85]. Research in this area should also consider larger sample sizes and ADHD severity and the presence of comorbid conditions should be reported for participants and accounted for during analysis.

Outcome measures for all interventions for ADHD need to be carefully planned. They should include core symptoms but it is likely that these are not the realistic targets of this type of intervention and goal-orientated outcomes agreed with YP and families may be more relevant. Functional and quality of life outcomes need longer follow-up but in a chronic disorder have far more significance. Finally, advancements in technology and improvements of the suitability of interventions specifically designed for independent use to facilitate self-management could involve a psychoeducational component. Such technologies should be co-designed with stakeholders including children and YP with ADHD adopting a user-centred design methodology to ensure the technology is suitable for this population.

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Compliance with ethical standards

Conflict of interest The authors declare that thay have no competing interest.

Appendices

Appendix 1: Medline search strategy

Database: Ovid MEDLINE(R) Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid MEDLINE(R) <1946 to Present>.

Search Strategy:

1. 1 (Attention Deficit and Disruptive Behaviour Disorders).mp. [mp = title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (2794)
2. 2 Attention Deficit.mp. and Disruptive Behaviour Disorders.tw. [mp = title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (458)
3. 3 Attention deficit hyperactivity disorder.mp. or exp Attention Deficit Disorder with Hyperactivity/(30903)
4. 4 Attention deficit hyperactivity disorder.tw. (19871)
5. 5 exp Attention Deficit Disorder with Hyperactivity/or ADHD.mp. (30310)
6. 6 ADHD.tw. (19992)
7. ADDH.mp. or exp Attention Deficit Disorder with Hyperactivity/(24810)
8. ADDH.tw. (116)
9. ADHS.mp. (613)
10. ADHS.tw. (480)
11. exp Attention Deficit Disorder with Hyperactivity/or exp Hyperkinesis/or hkd.mp. (28643)
12. hkd.tw. (127)
13. exp "Attention Deficit and Disruptive Behaviour Disorders"/or Attention$.mp. or exp Attention Deficit Disorder with Hyperactivity/(376528)
14. Attention$.tw. (331436)
15. behav$.mp. (1423228)
16. behav$.tw. (1039159)
17. dysfunc$.mp. (398233)
18. dysfunc$.tw. (355413)
19. exp Conduct Disorder/or exp Attention Deficit Disorder with Hyperactivity/or disorder$.mp. (1738736)
20. disorder$.tw. (923795)
21. disrupt$.mp. (242609)
22. disrupt$.tw. (236939)
23. defian$.mp. (2455)
24. defian$.tw. (2416)
25. impulsiv$.mp. (18368)
26. impulsiv$.tw. (16423)
27. exp Child Behaviour Disorders/or exp Attention Deficit Disorder with Hyperactivity/or inattentive.mp. (43637)
28. inattentiv$.tw. (2071)
29. exp Child Behaviour Disorders/or exp Attention Deficit Disorder with Hyperactivity/or inattention$.mp. (45482)
30. inattention$.tw. (4321)
31. hyperkinesis.mp. or exp Hyperkinesis/(4586)
32. hyperkin$.tw. (4500)
33. dysfunct$.mp. (398217)
34. dysfunct$.tw. (355398)
35. damage$.mp. (524409)
36. damage$.tw. (495785)
37. hyperactiv$.mp. or exp Attention Deficit Disorder with Hyperactivity/(57437)
38. hyperactiv$.tw. (48767)
39. exp "Disruptive, Impulse Control, and Conduct Disorders"/or exp Conduct Disorder/or conduct.mp. (67635)
40. conduct.tw. (59088)
41. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 (4116307)
42. limit 41 to (english language and humans) (2415834)
43. Child$.mp. (2191440)
44. Child$.tw. (1200130)
45. boy$.mp. (135421)
46. boy$.tw. (135106)
47. girl$.mp. (130008)
48. girl$.tw. (129971)
49. exp Adolescent/or exp Young Adult/or young person.mp. (2105981)
50. young person.tw. (839)
51. YP.mp. (961)
52. YP.tw. (961)
53. exp Adolescent/or exp Young Adult/or young people.mp. (2113601)
54. young people.tw. (21467)
55. exp Adolescent/or adolescen$.mp. (1892494)
56. adolescen$.tw. (226356)
57. teen$.mp. or exp Adolescent/(1840488)
58. teen$.tw. (26444)
59. youth$.mp. or exp Adolescent/(1855352)
60. youth$.tw. (57447)
61. 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 (3468618)
62. limit 61 to (english language and humans) (2625897)
63. exp Educational Technology/or Technology.mp. or exp Technology/(604158)
64. Technology.tw. (237611)

65. Assistive technology.mp. or exp Self-Help Devices/(10593)
66. Assistive technology.tw. (1210)
67. Self-help device$.mp. or exp Self-Help Devices/(9985)
68. Self-help device$.tw. (62)
69. exp Video Games/or game$.mp. (49816)
70. game$.tw. (45755)
71. exp Internet/or website$.mp. or exp Software/(196415)
72. website$.tw. (18842)
73. exp Internet/or exp Software/or download$.mp. (189332)
74. download$.tw. (9567)
75. exp Social Media/or exp Internet/or forum$.mp. (76225)
76. forum$.tw. (12505)
77. email$.mp. (5188)
78. email.tw. (4099)
79. mobile app$.mp. or exp Mobile Applications/(3202)
80. mobile app$.tw. (1452)
81. 63 or 64 or 65 or 66 or 67 or 68 or 69 or 70 or 71 or 72 or 73 or 74 or 75 or 76 or 77 or 78 or 79 or 80 (843422)
82. limit 81 to (english language and humans) (436105)
83. condition manag$.mp. (299)
84. condition manag$.tw. (296)
85. exp Self Care/or manag$.mp. (1264334)
86. manag$.tw. (1082943)
87. self-manag$.mp. or exp Self Care/(56314)
88. self-manag$.tw. (13985)
89. support.mp. or exp Social Support/(8752243)
90. support.tw. (807612)
91. exp Social Support/or support network$.mp. (63451)
92. [limit 93 to (english language and humans)] (0)
93. [limit 95 to last 5 years] (0)

Appendix 2: References and reasons for exclusion

References	Reason for exclusion
Barnett et al. [86]	Participants are teachers
Benyakorn et al. [87]	Not interventional
Bishop [88]	Intervention not technology
Bonarini et al[89]	Population focus not ADHD
Bul et al. [90]	Outcome measures do not assess ADHD-related difficulties
Chan et al. [91]	Not interventional
Chen et al. [92]	Not interventional
Christiansen et al. [93]	Intervention reliant on others
Dale and Grut [94]	Not exclusively for ADHD
Duffy [95]	Population focus not ADHD
Enebrink et al. [96]	Population focus not ADHD
Epstein et al. [97]	Intervention reliant on health care professionals
Fiellin et al. [98]	Population focus not ADHD
Frutos-Pascual et al. [99]	Population focus not ADHD
Frutos-Pascual and Garcia-Zapirain [100]	Participants typically developing, not ADHD
Gray et al. [72]	ADHD not primary diagnosis of participants
Halperin et al. [101]	Intervention not technology
Janeslätt et al. [102]	Intervention not technology
Kim et al. [103]	Intervention not technology
Lim et al. [104]	Intervention reliant on health care professionals
Mazurek and Engelhardt [105]	Not interventional
Myers et al. [106]	Participants ADHD diagnosis not confirmed
Nie et al. [107]	Intervention not technology
Pandria et al. [108]	Not interventional
Rohani et al. [109]	Participants ADHD diagnosis not confirmed
Rosch and Mostofsky [110]	Not interventional
Schafer et al. [111]	Participants not received ADHD diagnosis
Schuck et al. [112]	Participants not received ADHD diagnosis
Shah et al. 2012	Not interventional
Silva et al. [113]	Technology as outcome measure, not intervention
Steeger et al. 2016	Participants ADHD diagnosis not confirmed
Stephenson [114]	Population focus not ADHD
Tse et al. [115]	Intervention reliant on health care professionals
Vander et al. [116]	Intervention reliant on health care professionals
Wallace et al. [117]	Not interventional
Wehmeier et al. [118]	Intervention reliant on health care professionals
Wehmeier et al. [119]	Intervention reliant on health care professionals
Weinstein and Weizman [120]	Review
Wronska et al. [121]	Participants typically developing, not ADHD
Wronska et al. [122]	Participants not received ADHD diagnosis

Appendix 3: Details of Cochrane Risk of Bias quality assessment for included RCTs

Across the included RCTs three reported that the randomisation sequence was computer generated [34, 56, 57] and one reported minimization randomization [55]. These four

Study	Random Sequence Generation	Allocation Concealment	Blinding of Participants and Personnel	Blinding of Outcome Assessment	Incomplete Outcome Data	Selective Reporting
Bul, 2016 [34]	Low risk - computer program generated	Low risk - email allocation	High Risk - likely blinding could be broken	High risk - blinding could be broken	High risk - 20/88 (22%) in group one and 11/82 (13%) in group two reported as lost to follow-up. Analysed as ITT	Low risk - no protocol reported, but both primary and secondary outcomes assessed and results presented
Van der Oord, 2014 [57]	Low risk - computer program generated	Unclear - allocation reported as concealed but method not reported	Unclear - blinding of participants and personnel not reported	Unclear - blinding of outcome assessment not reported	Low risk - 3/21 (<20%) in experimental condition were non compliant with the intervention, not analysed as ITT	Low risk - no protocol reported, but both primary and secondary outcomes assessed and results presented
Dovis, 2015 [55]	Low risk - minimisation randomisation reported	Low risk - done by a person not involved in patient recruitment	Low risk - reported as double blind RCT	Low risk - reported as assessors blinded	Low risk - n lost from each group <20%. Analysis by ITT	Low risk - reports a study protocol
Weerdemeester, 2016 [56]	Low risk - computer program generated	Low risk - web-based allocation	High risk - blinding of participants not possible due to nature of study	Low risk - blinding assured	Low risk - <20% attrition rate.	Low risk - no protocol reported, but both primary and secondary outcomes assessed and results presented
Van Dongen-Boomsma, 2014 [51]	Unclear – reports stratified for age and gender, but not how randomisation was conducted	Low risk - done by a person not involved in patient recruitment	Low risk – reported as triple blind RCT	Low risk – reported as assessors blinded	Low risk - 1/27 (<20%) and 3/24 (<20%) reported as lost to follow up. Analysis by ITT	Low risk - no protocol reported, but both primary and secondary outcomes assessed and results presented
Egeland, 2013 [52]	Unclear – reports numbers corresponding to ID status were drawn	Low risk - done by a person not involved in patient recruitment	High risk - blinding of participants not possible due to nature of study	High risk – assessors not blinded	Low risk - 5/38 (<20%) in intervention group and 3/34 (<20%) in control group were reported as lost to follow up. No mention of what happens to missing data, no mention of ITT	Low risk – no protocol reported, but both primary and secondary outcomes assessed and results presented
Klingberg, 2005 [54]	Unclear – randomisaiton in blocks of 4 based on blinded list of numbers associated with CDs. Unclear how blinded list of numbers were generated.	Unclear – method not reported	Low risk – Reported as double blind	Low risk – reported as double blind	High risk - 7/27 (>20%) in intervention group and 2/26 (<20%) in control group reported as lost to follow up. Missing data not included in final analysis (not ITT)	Low risk - no protocol reported, but both primary and secondary outcomes assessed and results presented
Johnstone, 2012 [53]	Unclear – Sequence generation not reported	Unclear – method not reported	Unclear – blinding not reported	Unclear – outcome assessor blinding not reported	Unclear – drop out rate not reported, method of analysis for missing data not reported	Low risk - no protocol reported, but both primary and secondary outcomes assessed and results presented

RCT's were therefore judged as low risk of selection bias. Four of the RCTs randomization sequence was reported as unclear risk of bias due to lack of reporting of randomization sequence generation [51–54]. Five RCTs reported that treatment allocation was concealed [34, 51, 52, 55, 56] and were therefore judged at low risk of bias for this domain. Three RCTs were judged as unclear risk [53, 54, 57]. One RCT reported that blinding of participants and personnel could be broken [34] and two reported that blinding of participants and personnel was not possible due to the nature of the studies [52, 56]. These two RCTs were judged as having a high risk of bias for this domain. Two RCTs [53, 57] did not report on participant and personnel blinding and were judged as having an unclear risk of bias. Two RCTs were reported as double blind [54, 55] and one as triple blind (van boom) and were therefore judged as low risk for this domain. One RCT reported that blinding of the outcome assessor could be broken [34] and one RCT [52] reported that their outcome assessors were not blinded. These two RCTs were judged as having a high risk of bias. Two RCTs [53, 57] did not report on binding of their outcome assessor and were therefore judged as having an unclear risk of bias. Four of the included RCTs assured their outcome assessor was blinded and where therefore judged as having a low risk of bias for this domain. Two RCTs [34, 54] had a drop out rate of more than 20% and one RCT [54] did not include missing data in the final analysis. These two RCTs were therefore judged as having a high risk of bias for the incomplete outcome data domain. One RCT [53] was judged as unclear for this domain as their drop out rate and analysis method of missing data was not reported. The five remaining RCTs [51, 52, 55–57] were judged as having a low risk of bias for this domain as they all had less than a 20% drop out rate, and two of these conducted an ITT analysis [51, 55]. All eight of the included RCTs were judged as having a low risk of bias for the selective reporting domain. One of these reported a study protocol [55] and the remaining seven did not report a study protocol but did report on all of primary and secondary outcome measures [34, 51–54, 56, 57].

Appendix 4: Details of quality assessment for non-RCT studies

Three of the six included non-RCT studies presented clear aims and objectives [59, 60, 62]. All six studies described their outcome measures and their participants appropriately [58–63]. Four studies clearly described the intervention [59–61, 63]. None of the studies described confounding variables. Five studies clearly described their findings [59–63] and one study partially described their findings [58]. Accounting for participant loss to follow-up was not applicable to all six studies as participants did not drop out of these studies [58–63]. Four of the studies did not report probability values as no formal statistical analysis were performed [58–60, 63]. The statistical tests that were used in two of the studies [61, 62] were judged as inappropriate due to low sample sizes of two participants recruited to each of the studies [61, 62]. Overall, scores were low for external validity. None of the studies approached or recruited people who were representative of their target population (ref all), three of the studies involved individuals who are representative of the treatment the population would usually receive [59, 60, 63] and this was unclear to determine in three of the studies [58, 61, 62]. Overall, scores for internal validity were also low. No studies blinded participants or those who collected data, perhaps due to their non-RCT study designs. One study did not involve a follow-up data collection period [58], four studies had appropriate follow-up periods [59, 60, 62, 63], and one study did not have an appropriate amount of time between initial data collection and follow-up to determine an effect of their intervention [61]. Compliance with the intervention was reliable in four of the six studies [58–61] and unclear to determine in two of the studies [62, 63]. Two of the six studies used validated outcome measures [58, 63] and the other four studies did not [59–62]. Overall, the studies obtained low scores for the selection bias items of this scale. Two of the selected studies [59, 60] recruited all of their participants from the same population. This was unclear to determine in two of the studies [61, 62], inapplicable to one case study [58] and not the case for one study [63]. All studies recruited their study participants over the same period of time [58–63]. None of these studies used randomization for group allocation where applicable, as they are not RCTs and did not report adjusting any analyses for any confounding variables [58–63]. Due to low sample sizes, all six of the included non-RCT studies have been judged to not have sufficient power to detect a clinically important effect.

Appendix 5: Summary of outcome measurement quality assessment

Authors, year, country, study design	Measures of ADHD-related difficulties	Outcome measures where psychometric properties assessed	Outcome measures where psychometric properties not assessed	Analysis method appropriate
Bul, 2016, The Netherlands, RCT Crossover [Bul, 2016 #3776]	TMQ—parent and teacher completion, subscale Plan/Organise and working memory of BRIEF, Subscale of cooperation, responsibiity, assertiveness, self control and total SRRS of SRRS, IATQ, SRRS teacher version, self efficacy questionnaire	BRIEF, SRRS	TMQ, IATQ	Aggregated data used with ordinal scales
Van der Oord, 2014, The Netherlands, 2 arm RCT [van der Oord, 2014 #1330]	All eight subscales of BRIEF, DBDRS	BRIEF	DBDRS	Aggregated data used with ordinal scales (BRIEF, DBDRS)
Dovis, 2015, The Netherlands, 4 arm double blind RCT [Dovis, 2015 #6591]	Improvement index during training, Stop task Stroop, CBTT, WISC-III, TMT of D-KFES, Raven, DBDRS, BRIEF, SPRSQ-C, PedsQL, HSQ	Stop task, Stroop, CBTT, WISC-III, BRIEF, SPRSQ-C, PedsQL	Improvement index during training, D-KFES, Raven, DBDRS, HSQ	Yes
Bamford, 2016, USA, Single subject design (ABAB) [Bamford, 2016 #8050]	Guided reading packet, multiple choice	–	Guided reading packet, multiple choice	No formal statistical analysis presented, small sample size ($n = 4$)
Pinna, 2015, USA, Case series [Pinna, 2015 #8049]	Total time to complete reading, calculating time for distractions, time calculation	–	Total time to complete reading, calculating time for distractions, time calculation	No formal stats presented, small sample size ($n = 9$)
Ruiz-Manrique, 2016, Spain, Case stud [Ruiz-Manrique, 2014 #8048]	Conners parent Scale (brief version), Connors teacher rating scale, BSSQ, Conners CPT	Conners parent and teacher scales, Conners CPT	BSSQ	No formal stats presented, small sample size ($n = 1$), Conners CPT scores not presented
Weerdemeester, 2016, The Netherlands, Feasibility RCT [Weerdmeester, 2016 #8046]	AVL, Go/no-go task, MABC-2-NL	AVL, MABC-2-NL	Go/no-go task	Aggregated data used with ordinal scale for AVL
Shih, 2014, Taiwan, Before and after case series [Shih, 2014 #969]	Action detector and duration of arbitrary standing	–	Action detector and duration of arbitrary standing	No. Statistical significance should be interpreted with caution due to low sample size ($n = 2$)
Lin, 2016, Taiwan, Single case ABA design [62]	Three subtests in Mandarin Literacy Assessment	–	Three subtests in Mandarin Literacy Assessment	No. Statistical significance should be interpreted with caution due to low sample size ($n = 2$)
Rijo, 2015, Portugal, Before and after case series [63]	CPT II, WISC III	CPT II, WISC III	–	No formal stats presented, small sample sizes of ($n = 4$ and $n = 12$)
Van Dongen-Boomsma, 2014, The Netherlands, randomised placebo control trial [51]	ADHD-RS, BRIEF, Adapted digit span from WISC-III, Knox Cubes LDT, Sentences WPPSI-RN, Shortened Ravens Progressive Matrices, Day night stroop task, Sustained attention dots task version 02 k, Shape school	ADHD-RS, BRIEF, WISC III, stroop task, Knox cubes LDT, WPPSI-RN	Shortened Ravens progressive matrices, sustained attention dots task version 02 k, shape school	Yes
Egeland, 2013, Norway, RCT [52]	ADHD-RS, SDQ, BRIEF metacognition index,	ADHD-RS, SDQ, BRIEF	–	Aggregated data used with ordinal scale for SDQ
Klingberg, 2005, Sweden, double blind RCT [52]	WAIS-RNI, digit span from WISC-III, Stroop interference, Ravens coloured progressive matrices, Connors (parent and teacher versions)	WISC III, Connors, WAIS-RNI, Stroop interference	Ravens progressive colour matricies	Yes
Johnstone, 2012, Australia, randomised waitlist control [53]	WASI, SAST, counting span task	SAST, WASI	Counting span task	Aggregated data used with ordinal scales

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