Non-pharmacological interventions for adults with autism: a systematic review of randomised controlled trials

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Non-pharmacological Interventions for Adults with Autism: a Systematic Review of Randomised Controlled Trials

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Abstract

To determine the effects of non-pharmacological randomised controlled trials in adults with autism, a systematic review was conducted across five electronic databases. A total of 3865 abstracts were retrieved, of which 41 articles met all inclusion criteria: randomised controlled trial; non-pharmacological intervention; adults with autism; and English publication. Twenty included studies had strong methodological quality ratings. No meta-analysis could be performed due to heterogeneity between studies. Articles reported on interventions for (1) social functioning and language skills, (2) vocational rehabilitation outcomes, (3) cognitive skills training, and (4) independent living skills. Social functioning was the most studied intervention. *PEERS for young adults* and *Project SEARCH plus ASD support* interventions had the strongest evidence. Emerging evidence suggests non-pharmacological interventions could be effective.

Introduction

Autism spectrum disorder (ASD) is a complex neurodevelopmental disorder characterised by restricted and repetitive patterns of behaviours and persistent deficits in social interactions (American Psychiatric Association, 2013). Pervasive social, communication and adaptive behavioural difficulties emerge early in childhood and have lifelong effects on the psychosocial functioning of individuals with ASD into adulthood (Henninger & Taylor, 2012; van Heijst & Geurts,

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2015). ASD affects up to one in 59 children (Baio et al., 2018), with similar prevalence rates recorded in the adult population (Brugha et al., 2011). While adulthood comprises the majority of one's life and there will be a dramatic increase of approximately half a million young people with ASD transitioning to adulthood within the next decade, research beyond middle childhood is limited (Shattuck et al., 2012). Only an estimated 2% of ASD research funding is used to investigate lifespan issues for adults with autism in the US, with the majority of research funding spent on understanding the nature of ASD and improving early identification (Interagency Autism Coordinating Committee, 2016). This is concerning as the estimated national cost for adults with autism in the US is $175 billion dollars per annum (Buescher et al., 2014).

Cognitive, language, social functioning and behavioural outcomes are generally poor for adults with ASD (Magiati et al., 2014). Adults with autism reported difficulties with employment outcomes and independent living skills (Wise et al., 2019). In a systematic review of longitudinal follow-up studies Magiati et al. (2014) reported social integrational and independence outcomes for adults with ASD to be poor or very poor and employment outcomes to be low. While health, education and transition services for children with autism are relatively well established around the world, service provision tailored for adults is only starting to develop (Magiati et al.,

2014). While we expect a growing number of older adults with autism will seek clinical services, there are significant gaps in our knowledge of how to support this population. As such there is a need to identify efficacious interventions as that may reduce the economic impact of ASD, as well as improve health outcomes and quality of life.

A systematic review design is an appropriate methodology to consolidate evidence about interventions and inform recommendations for clinical service provision (Higgins & Green, 2011). In particular, a systematic review of randomised controlled trials (RCTs) can provide the highest level of evidence for interventions (Harbour, Miller,, & The Scottish Intercolleigate Guidelines Network Grading Review Group, 2001). While there have been attempts to consolidate the already limited research on interventions for adults with autism, another limitation is the lack of valid and reliable outcome measures for adults with autism, which further compromises attempts at treatment evaluation (Brugha et al., 2015).

In a systematic review of outcome measures used in treatment trials (*n*=30) for older adolescents and adults with autism, Brugha et al. (2015) found outcome measures used were inconsistent with frequent use of non-standardised assessments and limited use of measures designed for individuals with autism or measures focusing on core ASD deficits (i.e., social functioning or communication). Concerns around the use of outcome measures is also reported in a study by Bolte and Diehl (2013), where data from 195 prospective trials were evaluated. Bolte and Diehl (2013) reported identifying 289 different outcome measures. Of these, 61.6% were used once and 20.8% were investigator-designed. Furthermore, only three tools were used in more than 2% of the studies (Bolte & Diehl, 2013).

In a systematic review of psychosocial interventions for adults with autism, Bishop-Fitzpatrick et al. (2013) identified 13 studies, of which only four studies were RCTs. Most of the studies were single-case studies or non-randomised controlled trials, which reported on applied behaviour analysis or social cognitive training. While the number and quality of the studies were limited, results indicated a positive effect of psychosocial interventions for adults with autism (*d* = 0.14–3.59).

In another systematic review specific to behavioural interventions targeting adaptive skill building for young adults with autism, Palmen et al. (2012) identified 20 studies with 116 participants (sample sizes *n* = 1–22) with participants ranging from 16 to 55 years (mean age 16.5 years). Improvements were reported in 19 of the studies, which included a range of adaptive skills including social interaction skills, practical academic skills, vocational and everyday living skills. However, 15 of the included studies used a form of single subject design, with only 5 studies using a group design with non-randomised group assignment.

In a more recent systematic review, Hedley et al. (2017) identified 50 studies investigating the effects of vocational rehabilitation programs for adults with autism. Studies were included regardless of their design and Hedley et al. (2017) concluded that the current literature on vocational rehabilitation for adults with autism was limited by poor participant characterisation, small sample sizes, a lack of randomisation and use of appropriate controls.

The current study takes a step towards addressing some of the limitations identified in previous SRs in this area by including all types of non-pharmacological interventions for adults with ASD and by using the most robust evidence available. The aim of this systematic review was to identify and evaluate RCTs that investigated the effects of non-pharmacological interventions for adults with autism. We therefore aimed to (1) identify non-pharmacological interventions for adults with autism using a RCT design, (2) identify the intervention approach, reported outcomes and effectiveness of existing interventions, and (3) determine the methodological quality of the identified non-pharmacological intervention studies.

Method

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Liberati et al., 2009) guided the conduct and reporting of this review (see supplementary Table 1). The methods of the analysis and inclusion criteria were specified a priori and documented in the registration to the International Prospective Register of Systematic Reviews (*reference number removed*).

Eligibility Criteria

The inclusion criteria were as follows: (1) participants aged 18 years or over; (2) a diagnosis of ASD (including Asperger syndrome or Pervasive Developmental Disorder Not Otherwise Specified prior to the DSM-V) (American Psychiatric Association, 2013) and (3) a RCT design was used to determine the effectiveness of a non-pharmacological intervention. Studies containing young people with autism were only included provided adults aged 18 years or over were also in the sample. Studies were considered a RCT if participants were assigned to any group (intervention or comparison) by means of random assignment. To be included in the review, the intervention group must have received a non-pharmacological intervention and the comparison group could have received no intervention, intervention as usual or an alternate intervention.

We included all studies investigating the effects of non-pharmacological interventions (e.g., independent living/self-management skills, cognitive behaviour therapy, social functioning and vocational rehabilitation), which commonly address core features of ASD (i.e., social and communication

skills; restricted, repetitive patterns of behaviour, interests or activities; and adaptive behaviour and functional skills). However, biofeedback interventions were excluded. In addition, studies must have been published in English. Only original, peer-reviewed RCT articles were included. Conference abstracts, reviews, opinion pieces and study designs other than RCTs were excluded.

Information Sources and Search Strategies

A literature search was conducted in September 2020 using the following five electronic databases: CINAHL, EMBASE, ERIC, PsycINFO and PubMed. The full search strategies for each database are described in Table 1. Supplementary grey literature searches were conducted and reference lists were checked to identify studies.

Study Selection

One author independently screened all titles and abstracts of the retrieved articles against the inclusion criteria. To ensure rating accuracy, a second author independently screened a random sample of 40% of the abstracts, which was examined to determine the inter-rater reliability: Weighted Kappa = 0.87 (95% CI = 0.79–0.95). Where articles could not be excluded based on title and abstract, the reviewers assessed full papers for relevance independently. Disagreements about article inclusion between the reviewers were discussed and resolved by consensus within the research team.

Data Collection Process

A data extraction form was created to extract data from the included articles. Two authors were involved in extracting information about the methodological quality, study characteristics, intervention design, and main findings regarding intervention effectiveness independently. A third author checked all extracted data for accuracy and consistency. Data relating to the characteristics of the individual studies were extracted for: inclusion and exclusion criteria of participants, characteristics of the intervention and control groups, and screening and outcome measures. The Template for Intervention Description and Replication (TIDieR) checklist (Hoffmann et al., 2014) was used as a guide to extract the information relevant to the intervention design. This included the intervention aim, intervention materials (physical and informational), intervention procedures (activities and processes), intervention agent (who delivers the intervention), modes of delivery (how intervention is delivered), dosage (number of sessions, duration, intensity and dose), tailoring (planned adaptations), and modifications (modifications over intervention course).

Table 1 Search terms

Database and Search Terms (Subject Headings and Free Text Words)

CINAHL: (((MH "Autistic Disorder") OR (MH "Child Development Disorders, Pervasive") OR (MH "Pervasive Developmental Disorder-Not Otherwise Specified") OR (MH "Asperger Syndrome") OR (MH "Rett Syndrome")) AND (MH "Randomized Controlled Trials")) OR ((autism OR autistic OR ASD OR PDD OR PDD-NOS OR pervasive OR Asperger OR Rett OR (childhood AND disintegrative AND disorder*)) AND (RCT OR (Randomized AND Controlled AND Trial) OR (Randomised AND Controlled AND Trial) OR (Randomized AND Clinical AND Trial) OR (Randomised AND Clinical AND Trial) OR (Controlled AND Clinical AND Trial)) Limiters – Published Data: 20190901-20200931)

Embase: ((autism/ OR "pervasive developmental disorder not otherwise specified"/ OR Rett syndrome/ OR childhood disintegrative disorder/) AND (randomization/ or randomized controlled trial/ OR "randomized controlled trial (topic)"/ OR controlled clinical trial/)) OR((autism OR autistic OR ASD OR PDD OR PDD-NOS OR pervasive OR Asperger OR Rett OR (childhood AND disintegrative AND disorder*)) AND (RCT OR (Randomized AND Controlled AND Trial) OR (Randomised AND Controlled AND Trial) OR (Randomized AND Clinical AND Trial) OR (Randomised AND Clinical AND Trial) OR (Controlled AND Clinical AND Trial)) limit to yr="2019-Current")

Eric ((DE "Autism" OR DE "Pervasive Developmental Disorders" OR DE "Asperger Syndrome") AND (RCT OR (Randomized AND Controlled AND Trial) OR (Randomised AND Controlled AND Trial) OR (Randomized AND Clinical AND Trial) OR (Randomised AND Clinical AND Trial) OR (Controlled AND Clinical AND Trial))) OR ((autism OR autistic OR ASD OR PDD OR PDD-NOS OR pervasive OR Asperger OR Rett OR (childhood AND disintegrative AND disorder*)) AND (RCT OR (Randomized AND Controlled AND Trial) OR (Randomised AND Controlled AND Trial) OR (Randomized AND Clinical AND Trial) OR (Randomised AND Clinical AND Trial) OR (Controlled AND Clinical AND Trial))

PsycINFO: ((autism spectrum disorders/ OR rett syndrome/) AND randomized controlled trials/) OR ((autism OR autistic OR ASD OR PDD OR PDD-NOS OR pervasive OR Asperger OR Rett OR (childhood AND disintegrative AND disorder*)) AND (RCT OR (Randomized AND Controlled AND Trial) OR (Randomised AND Controlled AND Trial) OR (Randomized AND Clinical AND Trial) OR (Randomised AND Clinical AND Trial) OR (Controlled AND Clinical AND Trial)) Limiters –Published Date: 2019-current)

PubMed: (("Autistic Disorder"[Mesh] OR "Child Development Disorders, Pervasive"[Mesh] OR "Rett Syndrome"[Mesh] OR "Asperger Syndrome"[Mesh]) AND ("Randomized Controlled Trial" [Publication Type] OR "Randomized Controlled Trials as Topic"[Mesh] OR "Controlled Clinical Trial" [Publication Type] OR "Pragmatic Clinical Trials as Topic"[Mesh])) OR ((autism OR autistic OR ASD OR PDD OR PDD-NOS OR pervasive OR Asperger OR Rett OR (childhood AND disintegrative AND disorder*)) AND (RCT OR (Randomized AND Controlled AND Trial) OR (Randomised AND Controlled AND Trial) OR (Randomized AND Clinical AND Trial) OR (Randomised AND Clinical AND Trial) OR (Controlled AND Clinical AND Trial)) Filters: Publication date from 2019/09/13 to 2020/09/13)

Risk of Bias of Individual Studies

To assess the potential risk of bias for each study we used the Qualsyst critical appraisal tool, a commonly used quality assessment checklist for evaluating primary research papers from a variety of fields (Kmet et al., 2004). The checklist consists of 14 criteria used to assess the methodological quality of individual studies. Depending on the degree to which each criterion is met, a score between 0 and 2 is given (2 = meets the criterion; 1 = partially meets the criterion; 0 = does not meet the criterion). A total score was derived by adding up the scores from the 14 criteria, with the lowest possible score of 0 and the highest possible total score of 28 for RCTs. The total score was converted to an overall quality percentage score (a total score divided by 28 and multiplying that value by 100). An overall quality percentage score of 80% or higher indicates strong methodological quality, a score between 70% and 79% good quality, a score between 50% and 69% adequate quality, and a score below 50% poor quality. Two authors scored the included studies against the 14 criteria independently. Disagreements about the scoring between the raters were resolved by consensus.

Data Synthesis

After data were extracted using comprehensive data extraction forms, data were extrapolated and synthesized within a number of categories: participant characteristics, inclusion criteria, treatment conditions and outcomes, components of studies, components of the interventions, and methodological quality. The method to assess intervention outcomes were effect sizes and significance of findings. However, we could not conduct a meta-analysis due to heterogeneity in intervention designs and outcome measures used and the methodological quality of the included studies (Guolo & Varin, 2017).

Results

The process of study selection is illustrated in Fig. 1 (PRISMA flow diagram). The initial search using subject headings and free texts retrieved a total 3865 abstracts after duplicates were removed, with 41 articles meeting the final eligibility criteria for this review (see Fig. 1). No additional articles were identified by grey literature searches and checking references of the included articles.

Description of Studies

The study characteristics of the 41 included articles are described in Table 2. The majority of the RCT studies ($n = 23$) were conducted in the US (Capriola-Hall et al., 2020; Cox et al., 2017; Eack et al., 2018; Faja et al., 2012; Gantman et al., 2012; Gentry et al., 2015; Gorenstein et al., 2020; Hayes et al., 2015; Laugeson et al., 2015; Maisel et al., 2019; McVey et al., 2016; McVey et al., 2017; Morgan et al., 2014; Murza et al., 2014; Oswald et al., 2018; Smith et al., 2014; Strickland et al., 2013; Van Bourgondien et al., 2003; Wehman et al., 2017; Wehman et al., 2014; Wehman et al., 2020; White et al., 2016; White et al., 2019), with three in Japan (Kumazaki et al., 2019; Kumazaki et al., 2017; Miyajima et al., 2016), three studies in the UK (Ashman et al., 2017; Gaigg et al., 2020); Russell et al. (2013) and Germany (Bölte et al., 2002; Mastrominico et al., 2018; Rosenblau et al., 2020) respectively, two studies in Spain (Garcia-Villamisar & Dattilo, 2010; Garcia-Villamisar et al., 2016), and the Netherlands (Spek et al., 2013; Wijker et al., 2020) respectively, and one study in Israel (Saban-Bezalel & Mashal, 2015), Sweden (Hesselmark et al., 2014) and Canada (Nadig et al., 2018), Nigeria (Akabogu et al., 2019), Australia (Tang et al., 2020) respectively. The studies spanned a period of 18 years, conducted between 2002 and 2020, with most studies published between 2014 and 2019 (see Table 2).

Participants

Across the 41 articles, there were a total of 846 adults with autism in the intervention groups and 819 in the control groups. Study sample sizes ranges from 218 (intervention group: 114; control group: 104) in McVey et al. (2017) to eight (intervention group: 2; control group: 4) in White et al. (2016). Only eight studies involved participants with an age group mean above the age of 30 years (Ashman et al., 2017; Gaigg et al., 2020; Garcia-Villamisar & Dattilo, 2010; Garcia-Villamisar et al., 2016; Hesselmark et al., 2014; Miyajima et al., 2016; Rosenblau et al., 2020; Spek et al., 2013). One study included adults older than 65 years of age (Gaigg et al., 2020), and five studies including adults aged 60 years or older (Ashman et al., 2017; Mastrominico et al., 2018; Russell et al., 2013; Spek et al., 2013; Wijker et al., 2020). There were considerably more male participants across all included studies except for Akabogu et al. (2019), three studies included only male participants in the intervention group (Bölte et al., 2002; Morgan et al., 2014; Strickland et al., 2013; Van Bourgondien et al., 2003) and two studies did not report the gender split (Faja et al., 2012; McVey et al., 2017). The total number of male participants was 610 compared with 270 female participants.

Measures for Confirming Diagnosis and Screening for Inclusion

Across the 41 included studies, 21 different standardised measures were used to screen for and confirm ASD diagnosis or other inclusion criteria (see Table 2). Participant diagnosis of ASD (including Asperger syndrome and PDD-NOS) was

Fig. 1 Prisma flow chart
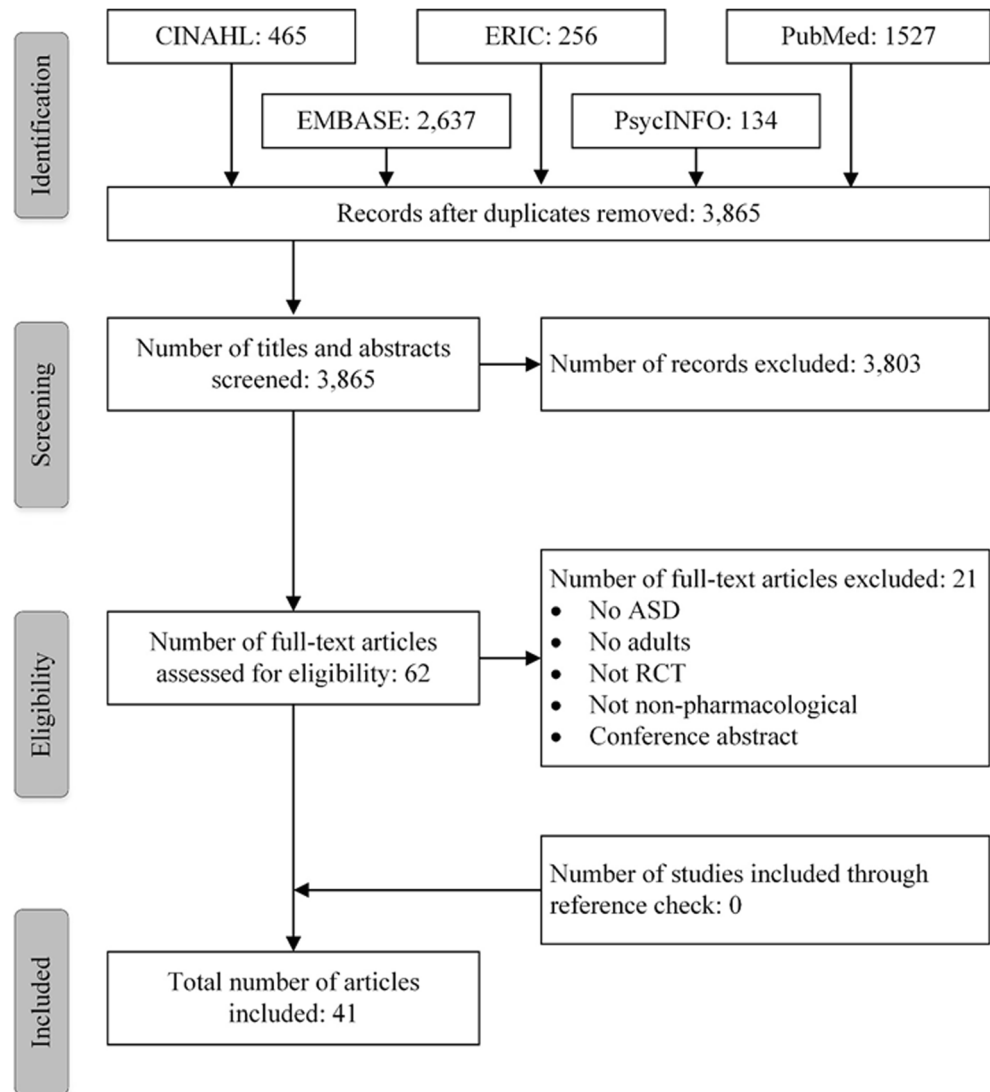
confirmed using a range of measures. The Diagnostic and Statistical Manual of Mental Disorders (DSM-IV; American Psychiatric Association, 2000; or DSM-V; American Psychiatric Association, 2013) was used to confirm the diagnosis of ASD in 14 studies (see Table 2). The Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2012) was used to confirm ASD diagnosis in 13 studies, the Autism Diagnostic Interview (ADI; Rutter et al., 2003) in five studies, and the International Classification of Diseases-10 (ICD; World Health Organisation, 1994) in two studies (see Table 2). Five studies used both the DSM and ADOS or ADI (Faja et al., 2012; Maisel et al., 2019; Morgan et al., 2014; Oswald et al., 2018; Spek et al., 2013), seven studies reported only using previous school or medical records to confirm diagnosis (Garcia-Villamisar & Dattilo, 2010; Gentry et al., 2015; Hayes et al., 2015; Murza et al., 2014; Strickland et al., 2013; Wehman et al., 2017; Wehman et al., 2020) and three studies referred to an existing diagnosis only

(Van Bourgondien et al., 2003; Wehman et al., 2014; Wijker et al., 2020). Of the 41 studies, 18 used two or more methods for confirming diagnosis (see Table 2).

Across the 41 included studies, a range of 19 different measures, in addition to ADOS or ADI, were used for screening of inclusion criteria (see Table 2). The Wechsler Abbreviated Scale of Intelligence (WASI or WASI-2; Wechsler, 2011) or Wechsler Abbreviated Scale of Intelligence (WAIS-III or WAIS-IV; Wechsler, 2008) was the most frequently used measure for screening inclusion criteria and was reported across 10 studies. The Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001) was reported across five studies and the Kaufman Brief Intelligence Test (KBIT; Kaufman & Kaufman, 2005), the Social Responsiveness Scale (SRS; Constantino, 2005), and the Pervasive Developmental Disorder–Autism Society Japan Rating Scale (PARS; PARS Committee, 2008) were each reported across three studies (see Table 2).

Table 2 Study characteristics

Study/country	Inclusion criteria*[1-21]	Groups (n = Sample size)	Group descriptive (Mean ± SD)	Outcome measures**[1-91]
Akabogu et al. (2019) / Nigeria	ASD (DSM-IV[1]); low social participation; English as the primary language	(I) Intervention (n=43): Language education intervention (II) Control (n=43): Waitlist	Age=23.36±1.10; Male: 32.6% Age=24.01±2.80; Male=41.9%	Social participation: SPQ[1]
Ashman et al. (2017) / UK	Diagnosis of ICD-10[2] Asperger Syndrome from SE Scotland ASD Consultancy Service. IQ >70; >18 yrs	(I) Intervention (n=10): Social Skills Group (II) Comparison (n=9): Social Interaction Group	Age=36.1 (22–61), IQ=109.0±19.1, Male:female 7:3, 'Voices' baseline: 'eyes' score= 22.8±5.3, 'Voices' score=14.8±2.6 Age=31.8 (19–55), IQ=103.6±23.8, Male:female 6:3, 'eyes' = 24.9±7.7, 'Voices'= 15.7 ±4.8	Social cognition: 'Reading the Mind in the Eyes' task and the 'Reading the Mind in the Voice' task. Generalisation of skills: SRS-2[2]; WFIRS-S[3]
Bölte et al. (2002) / Germany	HF-ASD or AS (ADI-R[3] and ADOS-G[4])	(I) Intervention (n=5): Computer facially expressed emotions (II) Control (n=5): Waitlist	Age=27.2±7.0; Male=100%; Raven=104.2±17.1 Characteristics for each group were not described	Facially expressed emotions: face and eyes tests; Ratings of IAPS[4] stimuli
Capriola-Hall et al. (2020) / USA	ASD (ADOS-2[4]); WASI[5]> 80; no unmanaged psychopathology; student or family currently not in therapy or service	(I) Intervention (n=16): Stepped Transition in Education Program (STEP) (II)Control (n=16): Transition as Usual	Age=19.87±1.92; Male: 68.75% Age=19.63±2.25; Male: 81.25%	Anxiety/depression: ASR[5] Loneliness: UCLALS[6]
Cox (2017) / USA	ASD, SRS-2[6], BRIEF[7], and BASC-2[8] to confirm ASD. 15.5–25 yrs, Guardian for car driving at home	Participants with ASD (n=51) allocated to one of four groups - Routine Training or one of three variations of VRDST	Routine Training: mean age 17.7, 73.9% male Standard: mean age 17.9, 85.8% male Automated: mean age 17.9, 85.7% male Eye tracking: mean age 18.1, 72.7% male	Virtual reality driver simulation training with both executive function and tactical tests and eye-tracking.
Eack et al. (2018) /USA	ASD (ADOS-2[4] or ADI-R[3])	(I) Intervention (n = 29): Cognitive Enhancement Therapy (CET) (II) Control (n = 25): Enriched Supportive Therapy (EST)	Age=22.5±6.4, Male=83%, white=93%, attended college=52%, employed=24%, Living independently=14%, IQ=108.7±13.9 Age=23.6±5.6, male=92%, white=68%, attended college=80%, employed=40%, living independently=17%, IQ=105.4±15.7	Neurocognition: MCCB[7] Social cognition: MSCEIT[8], Penn Emotion: Recognition Test, Discrimination Test, Acuity Test, Social Cognition Profile, SRS[2] Employment: MRAI[9]
Faja et al. (2012) / USA	HF-ASD (ADOS[4], ADI-R[3] and DSM-IV[1]); WAIS[5]> 85; Impaired face recognition (Benton/WMS)	(I) Intervention (n=9): Face recognition training (II)Control (n=9): Computer-house recognition training	Age=22.4 ±4.4; ADOS=12.1 ±4.1; ADI-RSI=17.4 ± 7.0; Benton=42.0 ± 3.6; WAIS=116.3 ± 16.3 Age=21.5 ± 5.6; ADOS=10.4 ± 2.6; ADI-RSI=17.5 ± 5.0; Benton=43.9 ± 2.6; WAIS=118.3 ± 17.4	Facial recognition (Standardised): BTFR[10], WMS[11], ERP[12], Face processing accuracy/time: Identifying interrupter in interview
Gaigg et al. (2020) / UK	ASD (DSM-IV[1], DSM-5[1]); not receiving any psychological therapy	(I) Intervention (n=14): Mindfulness-based course (MBT) (II)Intervention (n=9): CBT (III) Control (n=16): Waitlist	Age=42.5±10.3; Male: female 12:2; Full-scale IQ=111.7±12.1; ADOS-total=8.8±3.6; AQ=32.4 ±5.7; SRS-total=67.1±12.8 Age=40.3±12.7; Male:female 8:1; Full-scale IQ=116.7±12.5; ADOS-total=6.8±1.7; AQ=34.2 ±6.1; SRS-total=69.4±5.8 Age=45.7±13.6; Male:female 12:4; Full-scale IQ=117.6±15.5; ADOS-total=7.9±3.8; AQ=35.8 ±8.7; SRS-total=65.4±12.8	Generalised anxiety: GAD-7[13] Social anxiety: LSAS[14] Trait anxiety: STAI-T[15] Bodily manifestations of anxiety: BAI[16] Secondary measures: HADS-D[17]; CORE-OMIU[18]

Table 2 (continued)

Study/country	Inclusion criteria*[1-21]	Groups (n = Sample size)	Group descriptive (Mean ± SD)	Outcome measures**[1-91]
Gantman et al. (2012) / USA	ASD; 18–23 yrs; KBIT[9] >70; AQ[10] ≥26; SRS[6] ≥65; VABS[11] ≤85; social problems	(I) Intervention (n=9): UCLA PEERS for Young Adults (II) Control (n=8): Waitlist	Age=19.9±1.2; Male=55.6%; KBIT=96.7±11.8; AQ =35.9±5.2; SRS=110.8±22.6 Age=20.9±2.0; Male=75%; KBIT=108.5±17.4; AQ=32.8±4.3; SRS=102.6±18.3	*Social skills* (Primary measures): SRS[2]; SSRS[19]; SELSA[20] *Social skills* (Secondary measures): EQ[21]; QSQ[22]; SSIS[23]; TYASSK[24]
Garcia-Villamisar and Dattilo (2010) / Spain	ASD/AS (medical record); No psychiatric illness or neurological disorders	(I) Intervention (n=37): Leisure program (II) Control (n=34): Waitlist	Age=31.49±4.83; Male=59.5%; Leiter=64.46±21.33 Age=30.06±3.44; Male=55.9%; Leiter=61.44±9.37	*Quality of life:* QOL[25], SSS[26]
Garcia-Villamisar et al. (2016) / Spain	ASD & ID (DSM-IV[1]); Presence of executive dysfunctions (Below 2 SD on DEX[12])	(I) Intervention (n=19): Therapeutic recreation (II) Control (n=18): Waitlist	Age=31.84 ± 6.07; Male=73.7%; Leiter=57.28 ±13.40; DEX=44.47 ± 13.34 Age=35.00 ± 6.36; Male=61.1%; Leiter=59.33 ±24.03; DEX=45.33±13.91	*ASD symptoms:* ASD-DA[27]; ASD-CA[27]; *Behaviour:* VABS[28] *Social skills:* MESSIER[29] *Well-being:* PWI-ID[30] *Cognitive:* DEX[31], CANTAB[32]
Gentry et al. (2015) / USA	ASD (school or medical record); Scheduled to begin government-funded employment placement supported by a job coach	(I) Intervention (n=26): Apple iPod Touch, from beginning of employment placement (II) Control (n=24): Same intervention after 12 wks work (Waitlist)	Age=25.0±9.9; Male=92%; Live w| parent= 77%; High school=65%; Conversant=65%; read=92% Age=22.9±6.2; Male=75%; Live w| parent= 92%; High school=71%; Conversant=71%; read= 92%	*Personal support:* CHART[33], SIS[34]; hrs worked per month; Cumulative hours worked; Number of job coaching hours *Work competence:* EPER[35]
Gorenstein et al. (2020) / USA	ASD (expert consensus and ADOS[4]); Verbal IQ≥70 (WAIS-IV[5])	(I) Intervention (n=11): Job Based Social Skills (JOBSS) curriculum (II) Control (n=11): Waitlist	Age=26.2±4.3; Male=90.9%; WAIS-IV FSIQ= 94.5 ±10.6; ADOS= 15.4±4.5; SRS-2 Self-report= 61.4 ±11.4; employment pre-intervention= 45.5% Age=26.3±7.4; Male=81.8%; WAIS-IV FSIQ= 84.3 ±21.3; ADOS= 13.3±4.1; SRS-2 Self-report= 57.9 ±7.7; employment pre-intervention= 18.2%	*Theory of mind:* RMET[36] *Social Skills:* SRS-2[2] *Employment status:* employment status and hours recorded
Hayes et al. (2015) / USA	ASD (school record); transition program for obtaining employment; perform employment duties	(I) Intervention (n=8): Mobile video modelling application (VidCoach) on iPod or iPhone (II) Control (n=7): Waitlist	All aged 18 years (except for one aged 17 years); Male=86.7%; All senior yr high school/graduated with continual services from transition program *Characteristics for each group were not described*	*Employment interview skills:* Evaluation of mock interview by interviewer *in vivo* and by researchers using a scoring rubric
Hesselmark et al. (2014) / Sweden	ASD (medical records, interviews, ADOS[4]); >18 years; Mainstream school. No intellectual disability, substance abuse/suicide	(I) Intervention (n=35): Group cognitive behavioural therapy (II) Intervention (n=40): Group recreational activity	Age=31.9±8.5; Male=49%; ADOS=11.4±4.6; Living independently= 82%; Employed=22%; psychiatric symptoms =88%; psychotropic medication=80% Age=31.8±9.6; Male=60%; ADOS=11.1±3.2; Living independently= 69%; Employed=35%; psychiatric symptoms= 82%; psychotropic medication=78%	*Quality of life, sense of coherence and self-esteem;* QOL[37], SOC[38], RSES[39], *ASD/psychiatric symptoms* SCL-90[40], AQ[41], BDI[42], ASRS[43]; *Global functioning:* CGI-S[44], CGI-I[44]; Self-reported well-being
Kumazaki et al. (2017) / Japan	ASD (DSM-5[1], PARS[13], AQ-J[10], 18–25 yrs, unemployed, scores >30 LSAS[14]	(I) Intervention Job interview training – android robot (n=7) (II) Control self-paced materials (n=8)	*Intervention:* Age=23.1±2.0, male:female=6:1, IQ= 75.3±13.8, AQ-J=27.1±1.9, LSAS= 68.1 ±19.1 *Control:* Age=23.5±3.5, gender 6:2, IQ= 69.9, AQ-J=28.4±3.2, LSAS= 63.9±22.3	Likert rating scales: self-confidence (participant rated); Rated job performance in interviews 7-point Likert scale; Salivary cortisol
Kumazaki et al. (2019) / Japan	ASD (DSM-5[1], PARS[13], AQ-J[10], 18–27 yrs, unemployed, scores >30 LSAS[14]	(I) Intervention (n=13): android robot interview training	*Intervention:* Age=21.9±2.6, male:female = 9:4,IQ= 86.5±12.4, AQ-J =30.8±7.2, LSAS= 43.9±12.5.	Likert rating scales for self-confidence (participant rated);

Table 2 (continued)

Study/country	Inclusion criteria*[1-21]	Groups (n = Sample size)	Group descriptive (Mean ± SD)	Outcome measures**[1-91]
		(II) Control (n=16): interview guidance teachers only	Control: Age=21.9±2.5, gender 12:1, IQ= 86.9± 12.1, AQ-J= 30.3±7.5, LSAS=43.8±9.1	Rated job performance in interviews 7-point Likert scale; Salivary cortisol
Laugeson et al. (2015) / USA	ASD; 18-24 yrs; KBIT[9] >70; AQ[10] ≥26; social problems; No psychiatric illness	(I) Intervention (n=12): UCLA PEERS for Young Adults (II) Control (n=10): Waitlist	Age=21.0±1.4; Male=77.8%; KBIT=107.5±18.8; AQ=32.7±9.8 Age=19.7±2.0; Male=75.0%; KBIT=102.2±13.9; AQ=37.0±5.5	Social skills: SRS[2]; SSRS[19]; QSQ[22]; EQ[21]; TYASSK[24]
Maisel et al. (2019) / USA	17yrs +, ASD (DSM-5[1]; ADOS-2[4]. IQ > 80 on WASI-2[8].	ASD group n=27 Neuro-typical (NT) group n=41 Cognitive defusion vs active neutral distraction technique	ASD: Male=27%; Caucasian=40%; age=24.4±6.2; IQ= 110.9±13; AQ=28.9±7.8; DASS-T=39.1±19.3 NT: Male=41%; Caucasian=52%; age=21.4±9.4; IQ= 110.3±9.5; AQ=16.3±5.9; DASS-T=18.6±11.9	AQ[41], DASS-21[45], CFQ[46], BAFT[47]
Mastrominico et al. (2018) / Germany	ASD (ICD-10[2]); 14-65 yrs. No psychotic or addictive disorder or IQ <70.	(I) Intervention (n=35) Dance Movement Therapy (II) Control (n=22) Waitlist	Total sample: Male 77.2%; German 94.6%; not married 82.5%; no partner 78.9%; medication 26.4%; co-morbid psychiatric disorders 26.3%	Empathy: CEEQ[48]; subscale Empathic Concern of the IRI[49]
McVey et al. (2016) / USA	HF-ASD, AS or NOS (ADOS-G[4]/medical records); 18–28 yrs; KBIT-2[9] >70; Desire for friends (MSC[15]); Parent-reported social difficulties	(I) Intervention (n=24): UCLA PEERS for Young Adults Program (II) Control (n=23): Waitlist	Age=20.9±3.3; Male=75%; Caucasian=83.3%; parent education Bachelor's= 75.1%; KBITS-2=93.4 ±22.9; ADOS-G=11.9±2.9 Age=19.5±1.7; Male=87%; Caucasian=90.9%; parent education Bachelor's= 52.1%; KBITS-2=90.6 ±23.1; ADOS-G=11.4±3.7	ASD symptoms: ADOS-G[50], SRS[2] Social skills: SSIS[23], QSQ-YA[22], TYASSK[24] Social empathy: EQ[21] Social loneliness: SELSA[20] Social anxiety: LSAS-SR[14]
McVey et al. (2017) / USA	HF-ASD (refers to McVey et al., 2016 for information)	(I) Intervention (n=114): UCLA PEERS for Young Adults (II) Control (n=104): Waitlist	Paper refers to McVey et al., 2016 for more information	TYASSK[24], SRS[2], SSIS[23], QSQ[22]
Miyajima et al. (2016) / Japan	ASD (DSM-5[1] and PARS[13]); <60 years; Education >9 years No dementia, brain disease	(I) Intervention (n=7): Cognitive remediation therapy (II) Control (n=7): Treatment as usual (Psychotherapy, drug tx)	Age=36.1±8.8; Male=42.9%; education yrs= 11.7± 2.4; WAIS=80.4±16.4; medication= 82.1± 186.4 Age=37.7±12.3; Male=71.4%; education yrs =12.8 ±1.4; WAIS=81.7±14.5; medication=215.0± 274.6	Cognitive: BACS-J[51], WCST[52]; CPT[53] Social: GAF[54], ScoRS-J[55], LASMI[56] Self-efficacy: GSE[57]
Morgan et al. (2014) / USA	ASD (DSM-IV[1]; ADOS[4]; Aged 18-36 years; Verbal IQ >70; High school graduate	(I) Intervention (n=13): Interview skills curriculum (II) Control (n=15): Waitlist	Age=25.1±5.9; Male=92.3%; ADOS-C=3.5±1.4; Vineland=78.5±13.3; school graduate=92.3%; Employed=53.9% Age=24.0±4.8; Male=100%; SB5=103±16.8; Vineland=76.1±9.8; school=93.3%;Employed=60%	Employment interview skills: SPS[58] Behaviour: VABS[28] Depressive symptoms: PHQ-9[59] Cognitive: SBS-5[60] Social interview: ADI[61]
Murza et al. (2014) / USA	HF-ASD/AS (medical record); Reading level >8th grade; Social interference (below 1 SD on TASIT[16])	(I) Intervention (n=13): ACT & Check comprehension strategy (II) Control (n=12): Waitlist	Age=28.1±6.1; Male=92.3%; school graduate= 30.8%; Employed=53.9%; relationship= 7.7% Age=24.2±4.3; Male=83.3%; school graduate= 50.0%; Employed=33.3%; relationship= 0%	Inference: IGIRT[62], Inference subtest of WGCTA[63] TASIT[64] Reading: MIRI[65]; Sentence subtests of GRADE[66]
Nadig et al. (2018) / Canada	ASD (ADOS-2[4]); 18-32yrs; absence of ID (IQ scores WASI[8]); not enrolled in a similar program	(I) Intervention (n=20): Transition support program (II) Control (n=10): Waitlist	Age=20.7±3.3; Male 58.8%; Vineland: social 56.2; daily living 68.6; communication 68.4; SDS 81.1 Age=23.3±4.6; Male 77.8%; Vineland: social 42.8; daily living 59.3; communication 53.0; SDS 79.1	Social: SCQ[67], Social Problem-Solving Task Behaviour: VABS-II[28], SDS[68], QoL-Q-Abrighed[69]

Table 2 (continued)

Study/country	Inclusion criteria*[1-21]	Groups (n = Sample size)	Group descriptive (Mean ± SD)	Outcome measures**[1-91]
Oswald et al. (2018) / USA	ASD (DSM, ADOS-2[3]); IQ >70 (WASI[5]); high school completed, no psychosis/conduct problems	(I) Intervention (n = 29): Career, Coping, Social Skills (ACCESS) (II) Control (n=15): Waitlist	Age=25.5±7.1; Male 75%; IQ 102.8; Caucasian 62.5%; live independently 31.3%; ADOS SA 10.9 Age=24.9±6.1; Male 64%; IQ 101.4; Caucasian 80%; live independently 24%; ADOS SA 9.2	*Social Adaptive:* ABAS3[70] *Self-determination:* SDSS[71]; CSES[72]; *Anxiety:* ASR[5]
Rosenblau et al. (2020) / Germany	ASD (DSM-IV[1]); no other neurological or Axis 1 psychiatric comorbidities	(I) Intervention (n = 25): social-cognitive training (SCOTT) (II) Control (n=23): non-social control training (NCT)	Age=34.5±9.2; Male=76%; ADOS= 10.4±3.5; MWT (vocabulary)=109.2±13.8; LPS (strategic thinking)= 119.6±13.1 Age=30.2±9.2; Male=56.5%; ADOS= 11.6±4.6; MWT (vocabulary)=108.1±11.7; LPS (strategic thinking)= 116.3±10.4	*Behavioural measures:* FP[73], MASC[74] *Neurological:* functional and structural MRI[75]
Russell et al. (2013) / UK	ASD (ADI[3], ADOS[4]; 14-65 yrs; WAIS[5]/WISC[17] >70; OCD (YBOCS[18] >16, MINI[19]; Stable medication.	(I) Intervention (n=23): Exposure/response based CBT (II) Control (n=23: Anxiety management	Age=28.6±11.3; Male=82.6%; ADOS=10.7±4.2; Verbal IQ=102.5±16.7; YBOCS=24.8±3.7 Age=25.2±13.5; Male=69.6%; ADOS=9.9±4.7; Verbal IQ=97.3±15.3; YBOCS=25.1±5.2	*OCD:* YBOCS[76] (Item 11) *Anxiety:* CGI[44], CGI-I[44], DYBOCS[76]; OCI-R[77]; BDI[42]; BAI[16]; LSAS[14]; WSAS[78]; SCAS[79]; CHOCHI-R[80]; FAS-PR[81]
Saban-Bezalel and Mashal (2015) / Israel	PDD-NOS or AS diagnosis (DSM-IV[7]; AQ[10] >26; Right-handed; normal vision; No reported neurological disorders; Education ≥ 12 years	(I) Intervention (n=16): sessions analysing/generating irony (II) ASD control (n=13): Waitlist rated video clips (III) TD control (n=22): Waitlist rated video clips	Age=28.16±6.19; Male=56.25%; TONI-3=37.06 ±4.46; WAIS-III (vocabulary)=44.56 ± 7.17 Age=24.36±4.12; Male=84.62%; TONI-3=35.31 ±7.17; WAIS-III (vocabulary)=42.69 ± 8.92 Age=27.45±3.94; Male=59.09%; TONI-3=39.14 ±3.98; WAIS-III (vocabulary)=47.95 ± 4.20	*Comprehension of irony:* Irony questionnaire (interpreting 15 short passages; 10 with ironic interpretation and 5 with literal interpretation)
Smith et al. (2014) / USA	ASD (SRS-2[6] ≥60); Reading level ≥6th grade (WRAT-IV[20]; Un/underemployed; No vision/hearing problems.	(I) Intervention (n=16): Virtual reality job interview training (II) Control (n=10): Treatment as usual (Standard role-plays)	Age=24.9± 7; Male=75%; Prior employment= 62.5%; SRS-2=68.8±7.7; RBANS=89.8 ± 21.4 Age=23.2 ± 3.0; Male=80%; prior employment= 30%; SRS-2=65.7±11.1; RBANS= 89.0±19.2	*Interview skills:* Role-play performance; interview self-confidence; interview responses; Time with simulated interviews
Spek et al. 2013) / The Netherlands	ASD (psychologist, ADI-R[3] Dutch; DSM-IV[1]); 18-65 yrs; WAIS-III[5]>85; anxiety, depression or rumination.	(I) Intervention (n=21): Mindfulness-based therapy (II) Control (n=20): Waitlist	Age=44.4±11.1; Male=65.0%; SCL depression= 36.6 ±11.6; anxiety=20.9±8.4; RRQ=42.3±7.0 Age=40.1±11.0; Male=66.7%; SCL depression= 39.5 ±9.7; anxiety=21.8±6.3; RRQ= 42.3±8.8	*Self-report questionnaire of anxiety and depression symptoms:* SCL-90-R[40]; RRQ[82]; GMS[83]
Strickland et al. (2013) / USA	PDD (medical records) and HF-ASD or AS (caregiver report); 16–19 yrs; computer access; computer skills.	(I) Intervention (n=11): JobTIPS Web-based interview training (II) Control (n=11): Waitlist	Age=18.21±1.03; Male=100%; SES=6.70±1.16; Education=11.32±1.12; On medication=63.6% Age=17.66±1.27; Male=100%; SES=6.82±1.47; Education=11.00±1.33; On medication=63.6%	*Interview skills:* Interview Skills Rating Instrument *Social skills:* SRS[2]
Tang et al. (2020) / Australia	ASD (DSM-IV[1], DSM-5[1]); a stable medication regime, WASI-2[5]≥70; no neurological disorders and/or an acute mental health condition	(I) Intervention (n=11): MindChip (MC) with Mind Reading (MR) (II) Control (n=14): MR only	Age=22.64±6.56; Male:female 7:4; Full IQ=110.30 ±14.66; Performance IQ=111.20±14.83; Verbal IQ=107.20±15.60; On medication=45.5%; Employed: 27.3% Age=25.11±6.37; Male:female 9:5; Full IQ=106.21 ±15.35; Performance IQ=110.29±15.39; Verbal IQ=101.14±15.73; On medication=42.9%; Employed: 21.4%	*Mind Reading Battery,* MASC[74], ERSES[84], SRS-2[2], DASS[45], LSAS[14]
Van Bourgondien et al. (2003) /			Age=23.7±4.4; Male=100%; CARS=37.3±5.3; Intellectual level=3.7±0.8; Vineland=26.7±11.2	*Quality of treatment:* ERS[85]; Global Rating form (developed for study)

Table 2 (continued)

Study/country	Inclusion criteria[*1-21]	Groups (n = Sample size)	Group descriptive (Mean ± SD)	Outcome measures[**1-91]
USA	Adolescents and adults with ASD who applied for the treatment program at the Carolina Living and Learning Centre	(I) Intervention (n=6): TEACCH residential & vocational training (II) Control (n=10): Intervention in family home setting (III) Control (n=10): Intervention in a group home setting (IV) Control (n=6): Intervention in an institution setting	Age=26.6 ± 5.1; Male=80%; CARS=35.6 ± 6.9; Intellectual level=4.00 ± 1.3; Vineland=25.2 ± 11.5 Age=27.8 ± 8.5; Male=90%; CARS=34.7 ± 3.9; Intellectual level=3.70 ± 1.5; Vineland=24.9 ± 11.5 Age=21.5 ± 5.0; Male=66.7%; CARS=37.2 ± 2.9; Intellectual level=4.20 ± 1.0; Vineland =23.5 ± 8.6	Family satisfaction: Family Satisfaction Questionnaire (developed for the study) Participant skills: AAPEP[86] Participant behaviours: ABI[87]; VABS[28] (Maladaptive domain)
Wehman et al. (2014) / USA	ASD diagnosis, >18 yrs; Independent; eligibility for special education services in high school. No history of fire setting or drug abuse	(I) Intervention (n=24): SEARCH plus ASD support (II) Control (n=16): Treatment determined by Individualised Education Plans (IEPs)	Age=19.9±1.1; Male=75% IEP category: ASD= 66.7%; ID=25%; Speech language=0% Age=19.1±1.1; Male=68% IEP category: ASD=75%; ID=25%; other health=0%; Speech language=6.3%; Multiple=6.3%	Adaptive behaviour and intensity of support needs: SIS[34] Employment history: Employment status; Wage earned; Hours worked; Employer-paid benefits
Wehman et al. (2017) / USA	ASD diagnosis (medical records) or educational ASD; 18-21 yrs; Mainstream school; Independent.	(I) Intervention (n=31): Project SEARCH plus ASD (II) Control (n=18): Treatment as determined by their IEPs	Age=20.2±1.1; Male=77.4%; medication =35.5%; support=48.3%; Prior employment= 25.8% Age=19.3±1.4; Male=61.1%; medication=50%; support=53.3%; Prior employment =33.3%	Behaviour and support needs: SIS[34] Employment: Employment status; Wage; hrs worked; Employer-paid benefits
Wehman et al. (2020) / USA	As in Wehman et al. (2017) study above	(I) Intervention (n =81) Project SEARCH plus ASD Support (II) Control (n= 75) high school	Age 19.8yrs; Male 72%; White 57%; SRS=63.9 Age 19.5yrs; Male 84%; White 65%; SRS=63.6	ASD symptom: SRS-2[2]; Employment: Supports, wage & hrs worked at graduation & 1 yr post
White et al. (2016) / USA	ASD (ADOS-2[4]; clinical interview); >18 years; mainstream school No psychiatric illness	(I) Intervention (n=4): Virtual Reality brain computer interface (II) Intervention (n=4): College Living Success program (CLS)	Age=20.75 ± 1.71; WASI (IQ=126.75±5.62; ASD=100%; Comorbid psychiatric illness=100% Age=20.25 ± 1.71; WASI (IQ)=115.75±22.28; ASD=100%; Comorbid psychiatric illness=100%	Behaviour: BDEFS[88], SACQ[89] Global function: CGI-I[44] Participant satisfaction: College living satisfaction scale (Likert rating developed by authors)
White et al. (2019) / USA	ASD ('autism classification on Individualised Education Plan or ADOS-2[4]; WASI-II[5] Full Scale IQ ≥ 85; no unmanaged psychopathology, no receiving services considered redundant with the intervention	(I) Intervention (n=17): Stepped Transition in Education Program for Students with ASD (STEPS) – STEP 2 (II) Control (n=18): Transition as usual (TAU)	Age=19.94±1.88; FSIQ=103.87±14.95; SRS-2=67.43 ±8.41; Male=70.6%; Caucasian=82.4%; comorbid social anxiety disorder=52.9%; comorbid generalised anxiety disorder=58.8% Age=19.50±2.15; FSIQ=108.50±12.19; SRS-2=72.27 ±11.86; Male=72.20%; Caucasian=77.8%; comorbid social anxiety disorder=77.8%; comorbid generalised anxiety disorder=50.0%	Postsecondary student adjustment: SACQ[89] (primary outcome measure) Severity: ABCL[90], SRS-2[2]
Wijker et al. (2020) / Netherlands	ASD diagnosis 18-60yrs w/ normal-high intelligence; IQ >80; high score >19; PSS[21]	(I) Intervention (n=27) Dog assisted therapy (II) Waitlist (n=26)	Male 55%; dog at home 34%; age: 18-32 yrs = 36%, 33-46 yrs = 30%, 47-60 yrs = 34%; IQ mean = 102.1 (SD 13.7); stress mean = 22.1 (SD 6.2)	Stress: PSS[91], Psychological/ physical symptoms: SCL-90-R[40], Social: SRS[2], self-esteem: RSES[39]

*Inclusion screening tools name in full, abbreviation and author: [1] Diagnostic and Statistical Manual of Mental Disorders, fourth edition (DSM-IV/5; American Psychiatric Association, 2000, 2013), [2] International Classification of Diseases-10 (ICD; World Health Organisation, 1994), [3] Autism Diagnostic Interview-Revised (ADI-R; Rutter et al., 2003), [4] Autism Diagnostic Observation Schedule, 2nd Edition (ADOS-2; Lord et al., 2012; Lord et al., 2012)/Autism Diagnostic Observation Schedule-Generic (ADOS-G; Lord et al., 2012), [5] Wechsler Abbreviated Scale of Intelligence (WASI-2, WASI-III; Wechsler, 2011) or

Wechsler Adult Intelligence Scale (WAIS-V; Wechsler, 2008), [6] Social Responsiveness Scale 2nd edition (SRS-2; Constantino & Gruber, 2012), [7] Behavior Rating Inventory of Executive Functions (BRIEF), [8] Behavior Assessment System for Children, Second Edition (BASC-2; Reynolds & Kamphaus, 2004), [9] Kaufman Brief Intelligence Test—Second Edition (KBIT-2; Kaufman & Kaufman, 2005), [10] Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001), [11] Vineland Adaptive Behaviour Scales-Classroom Form (VABS; Sparrow et al., 2004), [12] Dysexecutive Questionnaire (DEX; Burgess, Alderman, Evans, Emslie, & Wilson, 1998), [13] Pervasive Developmental Disorder–Autism Society Japan Rating Scale (PARS; PARS Committee, 2008), [14] Liebowitz Social Anxiety Scale (LSAS; Liebowitz, 1987), [15] Mental Status Checklist (MSC; Gantman et al., 2012), [16] The Awareness of Social Inference Test (TASIT; McDonald, Flanagan, & Rollins, 2002), [17] Wechsler Intelligence Scale for Children (WISC; Wechsler, 2016), [18] Yale–Brown Obsessive Compulsive Scale (Y-BOCS; Goodman, Price, Rasmussen, Mazure, Delgado, et al., 1989; Goodman, Price, Rasmussen, Mazure, Fleischmann, et al., 1989), [19] Mini-International Neuropsychiatric Interview (MINI; Sheehan et al., 1998), [20] Wide Range Achievement Test (WRAT; Wilkinson & Robertson, 2006), [21] Perceived Stress Scale (PSS; Cohen & Williamson, 1998)

**Outcome measures name in full, abbreviation and author: [1] Social Participation Questionnaire (SPQ), [2] Social Responsiveness Scale 2nd edition (SRS-2; Constantino & Gruber, 2012), [3] Weiss Functional Impairment Rating Scale Self-Report (WFIRS; Canadian Attention Deficit Hyperactivity Disorder Resource Alliance, 2011), [4] International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1995), [5] ASEBA Adult Self Report (ASR; Achenbach & Rescorla, 2003), [6] UCLA Loneliness Scale (UCLLS; Hughes, Waite, Hawkley, & Cacioppo, 2004), [7] MATRICS Consensus Cognitive Battery (MCCB; Green & Neuchterlein, 2004), [8] Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT; Meyer, Salovey, & Caruso, 2002), [9] Major Role Adjustment Inventory (MRAI; Hogarty, Goldberg, Schooler, & The Collaborative Study Group, 1974), [10] Benton Test of Facial Recognition (BTFR; Benton, Sivan, Hamsher, Varney, & Spreen, 1983), [11] Wechsler Memory Scale–Third Edition (WMS-III Wechsler, 1997), [12] Event Related Potentials (ERP), [13] General Anxiety Disorder-7 (GAD-7; Spitzer, Kroenke, & Williams, 2006), [14] Liebowitz Social Anxiety Scale (LSAS; Liebowitz, 1987), [15] State-Trait Anxiety Inventory (STAI-T; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), [16] Beck Anxiety Inventory (BAI; Beck, Epstein, Brown, & Steer, 1988), [17] Hospital Anxiety and Depression Scale (HADS-D; Zigmond & Snaith, 1983), [18] Outcomes in Routine Evaluation—Outcome Measure (CORE-OM; Evans et al., 2000), [19] Social Skills Rating System (SSRS; Gresham & Elliott, 1990), [20] Social and Emotional Loneliness Scale for Adults (SELSA; DiTommaso & Spinner, 1993), [21] Empathy Quotient (EQ; Baron-Cohen & Wheelwright, 2004), [22] Quality of Socialization Questionnaire (QSQ; Frankel & Mintz, 2008), [23] Social Skills Improvement System-Rating Scales (SISS-R; Gresham & Elliott, 2008), [24] Test of Young Adult Social Skills Knowledge (TYSSAK; Adapted from Laugeson & Frankel, 2010), [25] Quality of Life Questionnaire/-Spanish version (QOL.; Caballo, Crespo, Jenaro, Verdugo, & Martinez, 2005; Shalock & Keith, 1993), [26] Stress Survey Schedule for Persons with Autism and Other Pervasive Developmental Disabilities (SSS; Groden et al., 2001), [27] Autism Spectrum Disorders—Diagnosis for Adults (ASD-DA; Matson, Wilkins, Boisjoli, & Smith, 2008)/Autism Spectrum Disorders—Comorbidity for Adults (ASD-CA; Matson & Boisjoli, 2008), [28] Vineland Adaptive Behavior Scales—Second Edition (Vineland-II; Sparrow et al., 2004)/ Vineland Adaptive Behaviour Scales-Classroom Form (VABS; Sparrow, Balla, & Cicchetti, 1984), [29] Matson Evaluation of Social Skills for Persons with Severe Retardation (MESSIER; Matson, 1995), [30] Personal Well-Being Index—Intellectual Disability (PWI-ID; Cummins, Lau, Davey, & McGillivray, 2010), [31] Dysexecutive Questionnaire (DEX; Burgess et al., 1998), [32] Cambridge Neuropsychological Test Automated Battery (CANTAB; Robbins et al., 1994), [33] Craig Handicap Assessment and Rating Technique (CHART; Whiteneck, Charlifue, Gerhart, Overholser, & Richardson, 1992), [34] Supports Intensity Scale (SIS)—Employment Subscale (Thompson et al., 2004), [35] Employee Performance Evaluation Report (EPER; Virginia Department of Aging and Rehabilitation Services, 2009), [36] Reading the Mind in the Eyes Test (RMET; Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Baron-Cohen et al., 2001), [37] Quality of Life Inventory (QOLI; Frisch, 1994), [38] Sense of Coherence (SoC) scale (Antonovsky, 1993), [39] Rosenberg Self-Esteem Scale (RSES; Beck, Steer, & Brown, 1996), [40] Symptom Checklist 90 (SCL-90; Derogatis & Cleary, 1977), [41] Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001), [42] Beck Depression Inventory (BDI; Beck, Steer, & Brown, 1996), [43] Adult ADHD Self-Report Scale (ASRS; Kessler et al., 2005), [44] Clinical Global Impression Scale–Severity (CGI-S) and Clinical Global Impression Scale–Improvement (CGI-I; Guy, 1976), [45] Depression Anxiety and Stress Scale-21 (DASS-21; Lovibond & Lovibond, 1995), [46] Cognitive Fusion Questionnaire (CFQ; Gillanders et al., 2014), [47] Believability of Anxious Feelings and Thoughts Questionnaire (BAFT; Herzberg et al., 2012), [48] Cognitive and Emotional Empathy Questionnaire (CEEQ; Savage et al in preparation), [49] Interpersonal Reactivity Index (IRI; Davis, 1983), [50] Autism Diagnostic Observation Schedule-Generic (ADOS-G; Lord et al., 2000), [51] Brief Assessment of Cognition in Schizophrenia-Japanese version (BACS-J; Kaneda et al., 2007), [52] Wisconsin card sorting test (WCST; Heaton, 1981), [53] Continuous Performance Test (CPT; Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956), [54] Global Assessment of Functioning (GAF; Piersma & Boes, 1997), [55] Schizophrenia Cognition Rating Scale-Japanese version (ScoRS-J; Kaneda et al., 2011), [56] Life Assessment Scale for the Mentally Ill (LASMI; no author reported), [57] Generalized Self-Efficacy Scale (GSE; Narita et al., 1995), [58] Social Pragmatic Scale (SPS; Morgan, 2011), [59] Patient Health Questionnaire-9 (PHQ-9; Spitzer, Kroenke, Williams, & Patient Health Questionnaire Study Group, 1999), [60] Stanford-Binet Intelligence Scale-Abbreviated Battery (SB5-ABIQ 5th Ed; Roid, 2003), [61] Autism Diagnostic Interview-Revised (ADI-R; Rutter et al., 2003), [62] Inference Generation in Reading Test (IGIRT; Murza, 2011), [63] WGCTA (Watson & Glaser, 1964), [64] The Awareness of Social Inference Test (TASIT; McDonald et al., 2002), [65] Metacognition in Reading Inventory (MIRI; Ehren, 2008), [66] Group Reading Assessment and Diagnostic Evaluation (GRADE; Williams, 2001), [67] Social Communication Questionnaire (SCQ; Rutter et al., 2003), [68] Self-Determination Scale (SDS; Wehmeyer & Kelchner, 1995), [69] Quality of Life Questionnaire-Abridged (QoL-Q-Abridged; Shalock & Keith, 1993), [70] Adaptive Behavior Assessment System—Third Edition (ABAS-3; Harrison & Oakland, 2015), [71] Self-Determination Skills Survey (SDSS; Carter et al., 2013), [72] Coping Self-Efficacy Scale (CSES; Chesney, Neilands, Chambers, Taylor, & Folkman, 2006), [73] Face Puzzle – implicit and -explicit tasks (FP; Kliemann, Rosenblau, Bölte, Heekeren, & Dziobek, 2013), [74] Movie for the Assessment of Social Cognition (MASC; Dziobek et al., 2006), [75] Magnetic resonance imaging (MRI), [76] Yale–Brown Obsessive Compulsive Scale (DYBOCS; Goodman, Price, Rasmussen, Mazure, Fleischmann, et al., 1989), [77] Obsessive Compulsive Inventory-Revised/Parent version (OCI-R; Foa et al., 2002), [78] Work and Social Adjustment Scale (WSAS; Mundt, Marks, Shear, & Greist, 2002), [79] Spence Children's Anxiety Scale (SCAS; Spence, 1998), [80] Obsessive Compulsive Inventory-Parent (CHOCHO-R; PR-CHOCI-R; Shafran et al., 2003), [81] Family Accommodation Scale-Parent Report (FAS-PR; Storch et al., 2007), [82] Rumination-Reflection Questionnaire (RRQ; Trapnell & Campbell, 1999), [83] Dutch Global Mood Scale (GMS; Denollet, 1993), [84] Emotion Recognition Self-Efficacy Scale (ERSES; Van Bourgondien, Reichle, Campbell, & Mesibov, 1998), [85] Environmental Rating Scale (ERS; Van Bourgondien, Schopler, & Caison, 1989), [86] Adult Psychoeducational Profile (AAPEP; Mesibov, Schopler, & Caison, 1989), [87] Autism Behavior Inventory (ABI; Van Bourgondien and Mesibov 1989), [88] Barkley Deficits in Executive Functioning Scale (BDEFS; Barkley, 2012), [89] Student Adaptation to College Questionnaire (SACQ; Baker & Siryk, 1989), [90] Adult Behavior Checklist (Achenbach & Rescorla, 2003), [91] Perceived Stress Scale (PSS; Cohen & Williamson, 1998)

Outcome Measures

Across the 41 included studies, 91 different outcome measures were used with only 18 of the 91 measures used in more than one study (see Table 2). The Social Responsiveness Scale (2nd Edition, SRS; Constantino, 2005) was used in 12 studies and was the most frequently used outcome measure. The Quality of Socialization Questionnaire (QSQ; Gantman et al., 2012), Test of Young Adult Social Skills Knowledge (TYASSK; Gantman et al., 2012) and Vineland Adaptive Behavior Scales (Second Edition) (2nd Edition, VABS; Sparrow et al., 2004) were each reported across four studies. The Empathy Quotient (EQ; Lawrence et al., 2004), Social Skills Improvement System-Rating Scales (SSIS-RS; Gresham & Elliott, 2008) or Social Skills Rating Scales (SSRS; Gresham & Elliott, 1990), Supports Intensity Scale (SIS; Thompson et al., 2004), Symptom Checklist 90 (SCL-90; Derogatis & Cleary, 1977) and the Clinical Global Impression-Improvement (CGI-I; Guy, 1976) were each reported across three studies. Some studies used multiple outcome measures to evaluate the same outcome (e.g., anxiety) and many used eight outcome measures or more (see Table 2).

Interventions

We categorised the 41 included studies which reported 38 non-pharmacological interventions (three studies reported two different non-pharmacological interventions into four intervention groups [see Table 3]; Gaigg et al., 2020; Hesselmark et al., 2014; White et al., 2016). Interventions were categorised into those aiming to improve (1) social functioning and language skills, (2) vocational rehabilitation outcomes, (3) cognitive skills training and (4) independent living skills. Social functioning and language skills interventions were most studied ($n = 20$), followed by cognitive training interventions ($n = 11$). Vocational rehabilitation was reported in 10 studies and only one study reported an independent living skills intervention (see Table 3). Across the 41 included studies, the interventions were compared to a waitlist control group ($n = 21$), alternate intervention ($n = 13$) or treatment as usual ($n = 7$; see Table 2).

Social Functioning and Language Skills Interventions

Interventions targeting social functioning and language skills included a range of approaches (see Table 3). Four studies evaluated a specific social intervention—the Program for the Education and Enrichment of Relational Skills (PEERS) for young adults, which aimed to improve social skills (Gantman et al., 2012; Laugeson et al., 2015; McVey et al., 2016; McVey et al., 2017). Seven studies evaluated interventions employing a social skills training-based component (Akabogu et al., 2019; Ashman et al., 2017; Gorenstein et al., 2020; Nadig et al., 2018; Oswald et al., 2018; Van

Bourgondien et al., 2003; White et al., 2016). All but one (Van Bourgondien et al., 2003) of these studies used weekly modules in a group setting. Of those using weekly modules in a group setting, all except two (Akabogu et al., 2019; Nadig et al., 2018) specified a component targeting skill generalisation (e.g., biweekly social outings, socialisation home-work tasks). All publications on the PEERS program reported significant improvements in the majority of areas targeted with both Gantman et al. (2012) and McVey et al. (2016) reporting medium to large effect sizes. Two studies reported significant improvements (Akabogu et al., 2019; Van Bourgondien et al., 2003), eleven reported mixed results (Ashman et al., 2017; Bölte et al., 2002; Garcia-Villamisar & Dattilo, 2010; Faja et al., 2012; Gorenstein et al., 2020; Hesselmark et al., 2014; Mastrominico et al., 2018; Oswald et al., 2018; Nadig et al., 2018; Murza et al., 2014; White et al., 2016), and three studies reported no significant improvements (Wijker et al., 2020; White et al., 2016; Saban-Bezalel & Mashal, 2015)

Three studies used computer-based facial recognition (Bölte et al., 2002; Faja et al., 2012; White et al., 2016). One study (Bölte et al., 2002) reported significant improvements on the affect recognition task, but not for behaviour modification, one improvement (Faja et al., 2012) and one no change (White et al., 2016). No effect sizes were reported.

Four studies used leisure or recreational therapy (Garcia-Villamisar & Dattilo, 2010; Garcia-Villamisar et al., 2016; Hesselmark et al., 2014; Mastrominico et al., 2018) and one study (Wijker et al., 2020) used a novel approach of dog assisted therapy to address social awareness and communication. In Garcia-Villamisar and Dattilo (2010) and Hesselmark et al. (2014), recreational therapy program was designed to improve QoL. Garcia-Villamisar et al. (2016) aimed to increase executive functions, social skills, adaptive behaviours and well-being and Mastrominico et al. (2018) empathy. All five studies reported mixed results, with significant improvements in some of the targeted areas (see Table 3). Hesselmark et al. (2014) and Mastrominico et al. (2018) reported no significant between group differences.

Only two studies focused on language skills and were language comprehension interventions (Murza et al., 2014; Saban-Bezalel & Mashal, 2015; see Table 3). Saban-Bezalel and Mashal (2015) found for both the Irony questionnaire and hemispheric processing, the ASD intervention group was significantly less accurate before ($p < 0.05$), but not after ($p > 0.05$) intervention compared to a typically-developing control group, with medium to large effect sizes reported. ASD controls remained significantly less accurate both before and after passive intervention ($p < 0.05$). Murza et al. (2014) reported mixed findings. Significant improvements were found for one inference generation reading measure and one metacognitive measure with small to large effect sizes reported. However, no significant improvements were found for social inference and reading comprehension.

Table 3 Summary of non-pharmacological interventions for adults with ASD

Intervention, goal and references	Intervention delivery, dosage	Materials and procedures	Tailoring and modifications	Main findings & authors' conclusions	Methodological quality
Interventions for social functioning and language skills					
Language education intervention (LEI) *Goal:* Effects of the intervention on social participation Akabogu et al. (2019)	*Delivery:* 6 small groups by 6 clinicians *Dosage:* 2hrs p/session x 28 sessions over 14 weeks (=56 hrs total)	Intervention involves language education techniques, cognitive behavioural techniques, rational emotive techniques and social coping techniques. No further information described.	None described	A significant increase in social participation among autistic emerging adults in the treatment group compared with those in the wait list control group ($p<0.01$)	**Adequate (64%):** Sampling strategy limited. Participant characteristics insufficiently described. Randomisation procedure not clearly described. Blinding of analysis only but not clear who was blinded. Outcome measure not reported in detail. Analytic methods are not reported but probably appropriate. Control of confounding not completely described. Effect size reported.
Social skills training *Goal:* Investigate if social skills training is more effective than non-specific support Ashman et al. (2017)	*Delivery:* Group delivery. Assistant psychologist administered the intervention *Dosage:* 1 hr per wk x 16 wks (16 hrs total)	Weekly topics covered (wks): introduction (1), emotion recognition (2), emotion recognition and responding (3), language and communication (4-7), family (8-9), friendships (10-11), employment (12-13), dating (14) and revision and close (15-16). Full manual http://patrickwildcentre. com/research/clinical-research/completed-studies/ intervention-studies/. Included role play, discussion groups, multimedia exercises. Home-work given to generalise activities beyond classroom.	None described	Both groups improved 'Eyes' task ($p= 0.05$), SRS-2 ($p =0.03$) and WFIRS-S ($p =0.053$). No significant difference between groups. Trend social skills group improved more on social cognition ($p \leq 0.1$ for group x time interaction). Not SRS-2 ($p=0.25$).	**Good (79%):** Sampling strategy insufficiently described. Participant characteristics and randomisation procedure sufficiently described. No blinding of participants/investigators. Estimates of variance provided. Insufficient data to assess sample size.
Computer-based facial recognition *Goal:* Improve facial affect recognition Bölte et al. (2002)	*Delivery:* Computer-based *Dosage:* 2 hrs per wk x 5 wks (10 hrs total)	500 adult face pictures expressing a range of affects. Participants judged the affect from seven basic emotions. If correct, visual and acoustic feedback was provided. If incorrect, a feedback sign, correct answer with explanation and comic strip example for the corresponding emotion was shown.	None described	Significant in reading mind in the face ($Z=1.9$, $p=.04$) and eyes-test ($Z=2.1$, $p=.03$) - only treatment subjects. No significant intended behaviour modifications.	**Adequate (54%):** Sampling, participant characteristics, randomisation procedure and results insufficiently described. Participants/investigators not blinded. Insufficient data to assess sample size.
Computer-based face recognition training *Goal:* Improve facial recognition	*Delivery:* Computer-based *Dosage:* 3 wks - max. 8 sessions. Session 0.5-1 hrs (4-8 hrs total)	Explicit rule-based teaching of 24 face pictures. Participants trained to move their eyes to encourage them to attend to eyes/entire face. Involved categorical face classifications (e.g. gender, age), using 15 activities (e.g. matching cropped and pixilated faces). For more detailed see: Faja et al.	Training discontinued after 8 sessions when behavioural criteria for 'expertise' met.	Both groups reached expert criteria. Treatment group increased in face inversion effect behaviourally and electrophysiologically. changes to faces (P100).	**Good (79%):** Sampling strategy appropriate and participant characteristics sufficiently described. Randomisation procedure not clear. No blinding.

Table 3 (continued)

Intervention, goal and references	Intervention delivery, dosage	Materials and procedures	Tailoring and modifications	Main findings & authors' conclusions	Methodological quality
Faja et al. (Faja et al., 2012)		(2008).			Insufficient data to assess sample size.
UCLA Program for the Education and Enrichment of Relational Skills for Young Adults Program (PEERS) *Goal:* Improve social skills Laugeson et al. (2015) Gantman et al. (2012) McVey et al. (2016) McVey et al. (2017)	*Delivery:* Licensed clinical psychologists. delivered PEERS in a face-to-face, group format (9-10 participants per group) *Dosage:* 14-16 weekly 90-minute sessions (21 hrs total) and homework assignments	PEERS is modified from UCLA PEERS for Adolescents Program (Laugeson & Frankel, 2010) to meet the needs of adults with ASD aged 18-23. PEERS consists of separate manualised group sessions for young adults and their caregivers run concurrently. Sessions with young adults provided instruction and rehearsal of social skills, (i.e., conversational skills, electronic communication, friendship networks, appropriate use of humour, dating etiquette, resolving arguments etc.). Training involved using concrete rules and steps, behavioural rehearsal exercises including role-play with modelling and structured practice with feedback. Socialisation homework was given and reviewed in the subsequent session. Caregiver sessions involved instructions on how to provide social coaching to young adults outside the PEERS sessions. A 10-minute reunification between young adults/caregivers was used to summarise newly learned sills.	Social coaching provided by the caregivers was tailored to the specific needs of the adults with ASD.	Gantman et al. (2012): Effective for close relationships, social and psychosocial functioning. Tx group improved significantly on social skills, empathy, social responsiveness and social get-togethers; with a significant decrease in loneliness and significant increase in social skills knowledge. Laugeson et al. (2015): replicated Gantman et al. (2012). Empathy change not significant. All other areas reported above were significant (ES: *d* = 0.92-2.57. Most gains maintained 16 wks post. McVey et al. (2016): Most results above replicated - significant med-large effect (partial η2=0.15-0.84). Social anxiety and loneliness not significant. McVey et al. (2017): No significant differences by gender - (*p* >0.05).	Gantman et al. (2012): **Good (79%)**: Sampling, participant characteristics and randomisation sufficiently described. No blinding of participants/investigators. Analytic methods not justified. Estimates of variance provided. Insufficient data to assess sample size. Laugeson et al. (2015): **Strong (82%)**: Sampling, participant characteristics and randomisation sufficiently described. No blinding participants/ investigators. Estimates of variance provided. Insufficient data to assess sample size. McVey et al. (2016): **Strong (86%)**: Sampling strategy appropriate. Randomisation described. No blinding participants/ investigators. Effect size provided. Power analysis for sample size conducted. McVey et al. (2017): **Strong (82%)**: Participant characteristics limited. No blinding participant/investigator
Leisure program (LP) *Goal:* Improve quality of life and reduce stress	*Delivery:* Staff in group format in community learning centre *Dosage:*2hrs p/day x5 days p/wk for 1yr (=520hrs)	LP included media, exercises, crafts, games, attending events (e.g. movies) and participating in social and youth groups. Participants were exposed to each activity and chose their preferred activity. Staff presented activities in several levels of	Activities based on individual's leisure patterns and interests. Participants could change activities if reluctant.	LP significantly decreased stress and increased 4 factors of QoL/total QoL measured (*p*<0.05). No significant improvement in social integration. ES NR.	**Strong (86%)**: Sampling strategy and participant characteristics sufficiently described. Randomisation procedure not described. Blinding of investigators

Table 3 (continued)

Intervention, goal and references	Intervention delivery, dosage	Materials and procedures	Tailoring and modifications	Main findings & authors' conclusions	Methodological quality
		difficulty with appropriate support so participants could participate.		No improvement in controls.	only. Insufficient data to assess sample size.
Therapeutic recreation-executive function (TR-EF) Goal: EF, social skill, adaptive behaviours, well-being Garcia-Villamisar et al. (2016)	Delivery: therapist group format, using face-to-face and computer-assisted methods Dosage: Five 1-hr sessions per week for 40 wks (200 hours total)	Based on neuropsychological rehabilitation activities to promote working memory, cognitive flexibility and inhibition- embedded within recreational activities (including instructional video games, computer tasks, manual activities). TR-EF uses hierarchical educational procedure where participants practise developing basic skills (e.g. spatial memory), followed by more complex EF (e.g. dimensional change card sort games).	If a participant experiences four consecutive failures in any activity, another set of activities was offered.	TR-EF significantly improved EF p<0.05 n2 effect sizes large. Significant improvement social skill, behaviour and well-being -large effect sizes. No significant improvement anxiety, attention deficit, depression / irritability.	
Strong (93%): Sampling strategy and participant characteristics described. Randomisation procedure reported. Blinding of investigators but not of participants. Analytic methods described/estimates of variance provided. Power analysis conducted. Effect size reported.					
Job-based social skills program (JOBSS) Goal: Improve social skills, higher rates of employment post-treatment Gorenstein et al. (2020)	Delivery: Group-delivered intervention, information sheet received each week regarding lesson introduced that week and ways of practice the skills. Lesson facilitated by a clinical psychologist. Dosage: 15 weeks in total	JOBSS incorporates elements from The Interview Skills Curriculum and the web-based interviewing skills program, JobTIPS. Lessons use a cognitive behavioural therapy (CBT) treatment modality, covering the topics of emotion regulation, problem solving, conversation skills, interview skills, and hidden social rules, amongst others. Each session follows a consistent agenda, which consists of: (1) transition time, (2) brief review of homework and previous session content, (3) psycho-education regarding weekly content area, (4) interactive activity based on new content (e.g., role plays, video self-modelling, worksheets), (5) distribution of	None described	No change with treatment for participants' ratings of their own social skills; significant improvements in social skills rated by caregivers between baseline and post-treatment in the JOBSS group (p = 0.005, Cohen's d = 0.52) but not the control group. At six-month follow-up, five of 11 Tx group members reported employment gain.	**Good (79%):** Sampling strategy limited. Participant characteristics sufficiently described. Randomisation procedure not clearly reported. No blinding of data collectors and participants. Estimates of variance provided. Effect size reported.

Table 3 (continued)

Intervention, goal and references	Intervention delivery, dosage	Materials and procedures	Tailoring and modifications	Main findings & authors' conclusions	Methodological quality
Recreational activity (RA) *Goal:* QoL, sense of coherence and self-esteem Hesselmark et al. (2014)	*Delivery:* nurse, social worker, occupational therapist, teacher. Face-to-face, group (6-8 adults) *Dosage:* 36 wkly x 3-hrs (=108 hrs).	homework, (6) wrap up of session and evaluation. The curriculum is fully manualised. RA relies on structure and group setting only, without providing deliberate techniques such as psycho-education/CBT. In the first session, participants were asked to write down group activities they want to engage in, which is turned into a list of activities by the therapists (e.g. board games, cooking). Participants vote for the next session's activity.	Topic/content of each session may vary depending on the activities chosen by the participants.	RA significantly improved QoL after intervention (*p* <0.01, *d* = 0.39). Medium ES. No changes to psychiatric symptoms. RA No significant differences when compared to CBT.	**Good (79%):** Sampling strategy and participant characteristics described. Randomisation procedure clearly described. No blinding of data collectors and blinding of participants not reported. Insufficient data to assess sample size.
Dance Movement Therapy (DMT) *Goal:* examine effects of DMT on empathy Mastrominico et al. (2018)	*Delivery:* 3 Institutions, 6 groups (5-10 people per group). Led by female DM therapists *Dosage:* 10 DMT sessions, 60min p/wk	Intervention followed manualized structure of DMT. Every dance movement session built from the same elements: warm up (10min), two mirroring exercises: dyadic movement (15-20 min), baum circle (20min) verbal reflection/ processing part (10-15min). The verbal processing and feedback after the movement intervention was intended to strengthen body awareness, self-awareness/self–other awareness, empathy, social skills.	None described	No significant changes in overall empathy between groups. Main effect of time significant for Emotional empathy (*p*= 0.001) and subscales Mirroring (*p*= 0.004) and Empathic Concern (*p*=0.030) - other scales not significant.	**Adequate (68%):** Sampling strategy limited. Participant characteristics sufficiently described. Randomisation procedure not clearly described. Blinding not reported. Insufficient data to assess sample size. Control of confounding not completely described.
Carolina Living and Learning Centre (CLLC) residential program Van Bourgondien et al. (2003) *Goal:* evaluate residential program	*Delivery:* CLLC Staff (not specified) *Dosage:* 24-hour program. Intervention duration across program not specified	CLLC program is a residential and vocational program based on the Treatment and Education of Autistic and Related Communication Handicapped Children (TEACCH) program. Psychoeducational model to increase independence. CLLC utilises farming and landscaping as its vocational curriculum. Treatment is individualised to teach new skills and decrease behaviour problems; and to use individual's strengths.	The teaching strategies were individualised but how they were individualised were not described.	Improved social skills, communication, visual systems to promote independence, use of developmental planning, positive behaviour strategies (*p*<0.05). CLLC rated more desirable/Families more satisfied. No ES.	**Good (75%):** Sampling strategy subject to bias, as only applicants to the experimental treatment program. Randomisation procedure not clearly described. No blinding. Estimates of variance provided. Insufficient data to assess sample size.
Acquiring Career, Coping, Executive control, and Social Skills (ACCESS) Program *Goal:* improve social, adaptive functioning, stress coping, and self-determination	*Delivery:* face to face group setting. The supervisor for ACCESS was a licensed Psychologist. The Participant Group leader a psychologist. And Social Coach Group leader a social worker *Dosage:* 19, 1.5h weekly lessons	Two introductory lessons and three modules: (1) *Stress and Anxiety Coping Skills* module identifying distorted thoughts and physical feelings associated with stress, anxiety and other emotions, CBT cognitive model, and cognitive restructuring tools (2) *Self-Determination Skills* module initiate, set goals, plan, organize, and self-advocate (3) *Adaptive* and *Social Skills* module friendships and social rules of the workplace. Lessons followed weekly structure: review previous topic, homework, presentation, group discussion of	Participants engaged in a structured vocational activity of their choice, outside the group for at least 3hrs p/wk. Social Coach leader consulted participants who didn't have a job to help them identify activities.	Compared to controls, treatment significantly (*p* <0.05) improved in adaptive and self-determination skills, per caregiver report, and self-reported greater belief in ability to access social support to cope with stressors. No significant group difference in Participant	**Good (79%):** Sampling strategy and participant characteristics sufficiently described. Randomisation procedure not clearly described. Blinding of participants and investigators not reported. Estimates of variance provided. Insufficient data to assess sample size.

Table 3 (continued)

Intervention, goal and references	Intervention delivery, dosage	Materials and procedures	Tailoring and modifications	Main findings & authors' conclusions	Methodological quality
Oswald et al. (2018)		topic, skill role-plays, and small group activities. Coach group covered same topics as participant group and educated on facilitating participant's use of skills learned.		self-reported Anxiety Problems or Composite Coping Self-Efficacy Scale ($p > 0.05$).	**Strong (89%):** Participant characteristics sufficiently described but sampling strategy limited. Randomisation procedure clearly described. Blinding of investigators only. Estimates of variance provided. Effect size reported.
Transition support program *Goal:* effect of program on self-determination and QoL Nadig et al. (2018)	*Delivery:* small groups (4-6 people) led by 2 graduate student facilitators *Dosage:* 10wkly, 2hr sessions	Transition support program curriculum modules, 1) *Social communication* includes initiating, listening, making an impression, perspective taking, nonverbal communication. 2) *Self-determination* includes preferences, interests and strengths, problem-solving, self-advocacy, self-regulation and choice making. 3) *Working with others* includes knowing your context, what makes good partners, preventing and resolving conflict. Getting the bigger picture and teamwork.	Curriculum guided by self-expressed needs. Modules selected for each group according to participants' needs.	Social problem-solving task ($p > 0.05$). *Self Determination scale total* not significant (cognitive problem-solving subscale $p = 0.04$). *Participant and parent skill change ratings* intervention effect on total score and each subdomains ($p = <0.05$).	**Strong (86%):** Sampling strategy and participant characteristics sufficiently described. Randomisation procedure clearly described. Blinding of investigators only. Effect size reported. Control of confounding not completely described.
Dog Assisted Therapy (DAT) *Goal:* Stress and agoraphobia, social awareness and communication Wijker et al. (2020)	*Delivery:* Face-to-face one-on-one. Therapists had degree in mental healthcare and specialised in ASD *Dosage:* 10 wkly sessions x60 min	Structured protocol. A therapy dog was involved during all therapy sessions. All of the participating dogs were trained and tested to work with people, and their mental and physical health care was strictly monitored by the service dog foundation. The study protocol about the DAT program has been described elsewhere (Wijker et al. 2017).	None described.	*Stress:* Non-significant. *Social responsiveness:* intervention effect -informant rated ($p = 0.01$; $d = 0.46$). Not significant for psychological/ physical symptoms, self-esteem, social response - participated rated.	
ACT & Check inference generation strategy intervention *Goal:* inference generation and metacognitive skills for reading Murza et al. (2014)	*Delivery:* by speech-language pathologist in face-to-face, groups (3-4 participants per group) *Dosage:* 2 x 1-hr sessions per wk - f6 wks (=12 hrs).	ACT & Check Strategy - four-step strategy to help participants generate inferences as they read, involving: 1. Ask yourself a question 2. Consider the text 3. Think about what you know, take a good guess (infer) 4. Check your guess. Five metacognitive skills critical to inference generation embedded in intervention: 1. Developing awareness of making inferences 2. Formulating questions about text 3. Integrating background knowledge 4. Attending to language cues 5. Applying knowledge/skills.	None described	Treatment group improved significantly on 1/2 inference generation reading and 1 metacognitive measure, compared to controls. No significance for social inference/reading. Small to large ES ($g = 0.21-1.2$). No generalisation to social communication.	**Strong (82%):** Sampling strategy appropriate and participant characteristics sufficiently described. Randomisation reported and procedure clearly described. No blinding of participants and investigators. Analytic methods described and estimates of variance provided. Insufficient data to assess sample size.
Irony comprehension *Goal:* Improve comprehension of irony	*Delivery:* speech pathologist, 6 teachers; group 3-5 participants *Dosage:* 5 x 30-40 min wkly (2.5-3.3 hrs total).	Short videos, stories and comic strips with ironic expression (from www.specialcomics.cet.ac.il) to practise ironic situations. Included introducing figurative language and irony; identifying irony (analysing expression/context, cues to irony,	None described	ASD intervention group similar to TD controls at first exposure (not significantly less accurate after intervention).	**Good (71%):** Sampling and participant characteristics not sufficiently described. Randomisation procedure not clearly described. No blinding of participants and

Table 3 (continued)

Intervention, goal and references	Intervention delivery, dosage	Materials and procedures	Tailoring and modifications	Main findings & authors' conclusions	Methodological quality
Saban-Bezalel and Mashal (2015)		discussing intention); generating short stories with ironic/literal endings.		Medium-large ES (range: partial $\eta2$ = 0.11-0.54).	investigators. Insufficient data to assess sample size.
College and Living Success program Goal: Self-regulation, social competence White et al. (2016)	*Delivery*: Clinical psychologist; individual/group. *Dosage*: 14 wkly sessions. Social outings biweekly.	CBT, mindfulness-acceptance, behaviour change and emotion recognition. Module examples: changing thought patterns, flexibility; meeting new people. Consisted of: (1) individual therapy for emotional regulation, (2) social outings to practice skills in naturalistic settings with peers; (3) coaching.	Coaching as needed	Both programs feasible and acceptable. No significant improvement on behavioural outcome measures. Sample size (n=8), no conclusions drawn about efficacy.	Good (75%): Sampling strategy appropriate and participant characteristics described. Randomisation reported but procedure not described. Blinding of participants and investigators not reported.
Virtual Reality Brain-Computer Interface Goal: emotion facial expressions, social interaction skills White et al. (2016)	*Delivery*: Computer based *Dosage*: semester 10-14 wks. 15-30 min session, 10 min set-up (40-min session average)	Training involved: (1) baseline attention /mediation level through single channel EGG reading with direct visual/textual feedback; (2) interaction with animated characters to follow clues and perform simple tasks; (3) scenarios describing typical social situations, where participants were required to interact with virtual agents using a keyboard/mouse.	Responses provided by virtual agents adjusted based on participants' attention level.	No consistent findings about improvement or worsening of outcome measures of college adjustment or EF for either program.	Good (75%): Sampling strategy appropriate and participant characteristics described. Randomisation reported but procedure not described. Blinding not reported. Insufficient data to assess sample size.

Interventions for vocational rehabilitation outcomes

Intervention, goal and references	Intervention delivery, dosage	Materials and procedures	Tailoring and modifications	Main findings & authors' conclusions	Methodological quality
Personal digital assistant (PDA) support Goal: Work performance, reduce work support Gentry et al. (2015)	*Delivery*: Occupational therapist; individually via assistive technology *Dosage*: 12 wks at workplace	Comprehensive and collaborative assessments identified appropriate assistive technology (iPod Touch-based PDA applications) and strategies for workplace. Occupational therapist trained and supported PDA use applications/strategies including task reminders, picture/video task-sequencing prompts, behavioural self-management, way-finding, and communication with the job coach.	Appropriate applications and strategies determined by comprehensive workplace assistive technology assessment.	Reduction in personal job coaching hrs (p= 0.02). Earlier PDA greater savings, no impact on support needed/vocational performance. No group difference in functional performance. ES NR.	Good (79%): Sampling subject to bias-only those who volunteered for intervention included. Participant characteristics sufficiently described. Randomisation described. Blinding not reported. Insufficient data to assess sample size.
Video-modelling application VidCoach Goal: interview skills Hayes et al. (2015)	*Delivery*: Individual -VidCoach - iOS application iPhone *Dosage*: VidCoach used for 1 month.	VidCoach application used to allow people to watch peer model videos/record own videos in response to system-delivered prompts (on iOS device). Participants provided with VidCoach application. Specific instructions on how to use VidCoach not given to the participants.	Interview questions for model videos collected from prospective employers.	Treatment group significant improvement in overall interview performance p <0.001. ES not reported.	Adequate (64%): Sampling strategy/subject characteristics limited. Randomisation procedure and blinding not described. Insufficient data to assess sample size.
Android Robot-Mediated interview Goal: for self-confidence, stress	*Delivery*: Face-to-face interview with android robot *Dosage*: 5 consecutive days (10 min mock interviews)	Days 1 and 5, both groups participated in 10-min mock job interview with human interviewer. Day 2-4, android robot-mediated group participated in similar 10-min mock interview, for 3 days. Scripts varied to promote engagement - same basic structure. Android-F (similar appearance to person)	Mock job application from six potential jobs, with questions concerning this job carried into interview.	Android robot-mediated marginally improved self-confidence (p = 0.08) and had significantly lower levels of salivary cortisol (p	Good (79%): Sampling strategy appropriate limited. Participant characteristics sufficiently described. Randomisation reported but procedure not

Table 3 (continued)

Intervention, goal and references	Intervention delivery, dosage	Materials and procedures	Tailoring and modifications	Main findings & authors' conclusions	Methodological quality
Kumazaki et al. (2017)		incorporated changes in facial expression (smiling, nodding)		= 0.045) compared to controls (human interview).	described. Blinding not reported. Estimates of variance provided. Effect size reported.
Job interview training Android Robot *Goal*: interview skills communication Kumazaki et al. (2019)	*Delivery*:Combined interview guidance by teachers and interview training program using an android robot *Dosage*: 7 days	Interview training program using android robot. Consists of following: (1) tele-operating android robot and conversing with others through the android robot, (2) face-to-face mock job interview with android robot, and (3) feedback based on mock job interview and nonverbal communication exercises using android robot.	Participants selected from range of jobs (e.g. data entry clerk, shelf stacker in a supermarket, Custodian)	Combined guidance (teachers and android robot) improved self- confidence, nonverbal communication and significantly lower levels of salivary cortisol vs only guided by teachers.	**Strong (86%)**: Sampling strategy appropriate. Participant characteristics described. Randomisation procedure not described. Blinding of investigators only. Estimates of variance provided. Effect size reported.
Interview skills curriculum (ISC) *Goal*: Improve social-pragmatic skills for job interviews Morgan et al. (2014)	*Delivery*: educator/ job coach; in face-to-face group *Dosage*: Wkly 1.5 hr sessions for 12 wks (18 hrs total)	Intervention session topics included (1) character, attitude and persona, (2) small talk, non-verbal communication and hygiene, (3) interview questions, closing the interview and follow-up. Intervention content was delivered in a variety of formats including discussion, role-play, video feedback, peer review, games and mock interviews.	None described (ISC follows a manualised intervention protocol)	Intervention group large significant gains in social pragmatic skills during mock interview. No significant improvements social skills (delta ES =1.09) or depression (delta ES -0.55).	**Strong (89%)**: Sampling strategy and participant characteristics described. Randomisation procedure not clearly described. Assessors/ coders blinded. Participant blinding not reported. Effect size provided.
Computerised virtual reality job interview training (VR-JIT) *Goal*: employment interview skills Smith et al. (2014)	*Delivery*: individual via computer software/internet *Dosage*:10 hrs (20 trials) of VR-JIT training over 5 sessions in 2-wks	Simulation >1,000 interview questions and 2,000 trainee responses. VR-JIT provides didactic e-learning guidance on employment interviews. Job-relevant interview content and interviewee performance targeted. Strategies included providing repeatable VR interviews, in-the-moment feedback, displaying scores on key performance dimensions.	Three levels of training; easy, medium, hard.	Improved interview skills significantly more than usual tx, ES moderate-large. Role play performance significant in tx group ($p=0.05$, $d=0.83$). Self-confidence ($p=0.06$, $d=1.15$).	**Good (79%)**: Sampling strategy not clearly described. Randomisation procedure not described. Blinding of raters reported. Analytic methods described and estimates of variance provided. Insufficient data to assess sample size.
Transition to employment program (JobTIPS) *Goal*: Improve employment interview skills Strickland et al. (2013)	*Delivery*: Web-multimedia interview training; individual virtual reality practice with clinician. *Dosage*: 2 interviews, 30-min practice interview	JoTIPS involves process of getting, keeping and leaving a job. Step-by-step instructions with icons, videos, worksheets, organisational tools, social narratives. Participants used written instructions to complete the 5 JobTIPS sections (and worksheets). Participants completed a virtual practice interview (simulation controlled remotely by a clinician 'interviewee'), with direct feedback. *Clinician had experience in autism intervention.*	Baseline identified improvement areas, for clinician to identify for feedback during practice session.	JobTIPS improved interview skills. More effective teaching interview content vs delivery skills. JobTIPS significant change on 2nd interview for content scale ($p<0.01$; large ES). Delivery skills ($p>0.05$).	**Good (79%)**: Sampling strategy not clearly described. Participant characteristics described. Randomisation procedure not described. Blinding of raters/ interviewer. Insufficient data to assess sample size.
Project SEARCH plus ASD	*Delivery*: Interdisciplinary team. On-site face-to-face	PS-ASD modified from disability non-specific Project SEARCH (Rutkowski et al., 2006) to meet	None described Participant and family members	Wehman et al. (2014): employed 88% tx vs. 6%	Wehman et al. (2014):

Table 3 (continued)

Intervention, goal and references	Intervention delivery, dosage	Materials and procedures	Tailoring and modifications	Main findings & authors' conclusions	Methodological quality
Supports (PS-ASD) *Goal:* Improve employment outcomes Wehman et al. (2014) Wehman et al. (2017) Wehman et al. (2020)	individual job coaching/internships and on-site face-to-face group classes. *Dosage:* 720 hrs internship (4 hrs a day) and 180 hrs of classes at the business (1.75 hrs per class) over 9 months (rotation through 3 internships).	needs of young adults with ASD (Wehman et al., 2012). Collaborative model for participants with ASD, their families, a local education agency, a local community rehabilitation program, the state vocational rehabilitation program and a host business. The local agency provided a teacher and instructional assistants. The vocational program provided funding and supervision for coaching services. The community rehabilitation program provided job coaches for on-site job coaching. The host business provided internship sites for job skills practice. Classes focused on learning job and social communication skills. On-site coaching focused on intensive, systematic instruction using applied behavioural analysis. Host business provided with training in PS-ASD. *Interdisciplinary team included special education teachers, instruction assistants, employment specialists, business liaisons.*	identified their personalised employment goals	controls (p=0.001, no ES). No between group difference for wages or supports. Tx group 78% employed with higher wages at 12 & 24 mths. Wehman et al. (2016): Tx group significantly more likely to be employed (87% vs.12%); and at 3 & 12 mths post (p<0.05). Between group differences for wages, hrs worked (p <0.05). Large ES. Wehman et al. (2019): 73.4% tx vs. 17% controls employed at/above min. wage by 1yr (p<0.05)	**Strong (82%):** Sampling strategy/participants described. Randomisation procedure clearly described. No blinding of participants and investigators. Insufficient data to assess sample size. Wehman et al. (2016): **Good (79%):** Sampling/ participants described. Randomisation procedure not described. No blinding of participants and data collectors. Estimates of variance provided. Insufficient data to assess sample size. Wehman et al. (2019): **Strong (82%):** Randomisation reported but procedure not described. No blinding of participants and investigators.

Interventions for cognitive skills training

Intervention, goal and references	Intervention delivery, dosage	Materials and procedures	Tailoring and modifications	Main findings & authors' conclusions	Methodological quality
Stepped Transition in Education Program for Students with ASD (STEPS) – STEP 2 *Goal:* Positive effect on adjustment to college, anxiety, depression and loneliness White et al. (2019) Capriola-Hall et al. (2020)	*Delivery:* one-on-one weekly counselling sessions (60 minutes for each); 4-6 counsellor-accompanied outings in the community and weekly check-ins either by telephone or email. *Dosage:* 12-16 weekly sessions, 15-20 h total of content delivery	STEPS emphasises self-awareness and acceptance of self, strengths-building, and goal-oriented behaviour; Utilises cognitive-behavioural techniques to build skills and address concerns related to positive adjustment to college, including advocating for one's self, meeting new people and integrating into social networks, managing stress, and developing life skills; a standardised manual. Participants had opportunities to practice skills related to self-advocacy, self-regulation, and self-determination both during the individual therapy sessions as well as during the community outings.	Personalization occurred with respect to the student's specific goals and needs.	White et al. (2019): A significant and positive immediate treatment effect in college adjustment (p=0.02); a very large immediate effect (d=1.248) and a moderate-to-large effect for 2 weeks after intervention cessation (d=0.644). Capriola-Hall et al. (2020): No significant interaction between time and Tx condition in anxiety and loneliness (p>0.05); STEPS had a significant decrease in depression	White et al. (2019): **Strong (86%):** Sampling strategy appropriate. Participant characteristics described. Randomisation procedure described. Blinding of participants and investigators not reported. Estimates of variance provided. Effect size reported. Capriola-Hall et al. (2020): **Good (79%):** Sampling strategy limited. Participant characteristics described. Randomisation procedure not described. Blinding of

Table 3 (continued)

Intervention, goal and references	Intervention delivery, dosage	Materials and procedures	Tailoring and modifications	Main findings & authors' conclusions	Methodological quality
				$(p<0.05, \eta^2 = 0.25)$.	participants and investigators not reported. Estimates of variance provided. Effect size reported.
Cognitive enhancement therapy (CET) *Goal:* Core cognition and employment Eack et al. (2018)	*Delivery:* Group and computer. Pairs then 6-8 participants after 3 months *Dosage:* 60hrs (over 18-months) 1.5hrs x weekly	Neurocognitive training inattention, memory, and problem-solving with 45 social cognitive group sessions to facilitate adult social-cognitive milestones (e.g., perspective-taking, cognitive flexibility). Session structure: welcome, homework presentation, in vivo social-cognitive exercise, lecture on new social cognition topic, and homework assignment (real world application).	Attempts to pair participants from similar age groups and construct developmentally homogeneous social cognitive groups	CET significant in neurocognitive function vs EST (d=.46, p=.013). CET/EST large social-cognitive improvements. CET vs EST participants significantly more likely to be employed p =0.023	**Strong (89%):** Participant characteristics sufficiently described but sampling strategy limited. Randomisation procedure clearly described. Blinding of investigators only. Estimates of variance provided. Effect size reported.
Be Mindful (Mindfulness-based therapy; MBT) *Goal:* Reduce anxiety and broader mental health difficulties Gaigg et al. (2020)	*Delivery:* online courses with the aim of completing the course in 6-8 weeks *Dosage:* not specified	Four modules with 10 different exercises explained in instructional videos and audio files that participants gain access to as they progress through the course: to cultivate present moment awareness and non-judgmental attitudes towards thoughts and feelings as they arise. (https://www.bemindfulonline.com/)	None described	The main effect of time across all measures was significant in the MBT ($p<0.05$) with large effect size (partial η^2 = 0.71); no significance in the waitlist group (p=0.248) where the effect size was small (partial η^2 = 0.26).	**Strong (82%):** Sampling strategy/participants described. Randomisation procedure not described. No blinding of participants and investigators. Estimates of variance provided. Effect size reported.
Serenity program (self-help cognitive-based therapy; CBT) *Goal:* Reduce anxiety and broader mental health difficulties Gaigg et al. (2020)	*Delivery:* online courses with the aim of completing the course in 6-8 weeks *Dosage:* not specified	*CBT:* Eight sections based on trans-diagnostic CBT principles and aims to help people understand the nature of their anxiety and how to manage it through exercises that are presented in 12 illustrated slides. (https://serene.me.uk)	None described	The main effect of time across all measures was significant in the CBT ($p<0.05$) with large effect size (partial η^2 = 0.79); no significance in the waitlist group (p=0.248) where the effect size was small (partial η^2 = 0.26).	**Strong (82%):** Sampling strategy/participants described. Randomisation procedure not described. No blinding of participants and investigators. Estimates of variance provided. Effect size reported.
Cognitive behavioural therapy (CBT) *Goal:* Improve QoL, sense of coherence and self-esteem Hesselmark et al. (2014)	*Delivery:* CBT trained psychiatrist and psychologist. Face-to-face, structured group (6-8 participants) *Dosage:* 36 wkly x 3-hrs (=108 hrs)	Psycho-education, social training and cognitive behavioural techniques-3 modules (self-esteem, ASD awareness, social contacts, everyday life and psychosocial/physical health). Sessions included (1) agenda, (2) homework review, (3) lecture/-discussions, (4) social break, (5) relaxation/mindfulness exercise, (6) topic discussions/exercises, (7) homework (8) evaluation.	None described	CBT significantly improved QoL (p =0.02, d=0.31) and at follow-up (p =<0.01, d=0.39). Medium ES. No changes to psychiatric symptoms. No significant differences CBT vs recreational activity intervention.	**Good (79%):** Sampling strategy and participant characteristics described. Inclusion/exclusion criteria not well defined. Randomisation procedure described. No blinding of data collectors. Blinding not reported. Insufficient data to assess sample size.

Table 3 (continued)

Intervention, goal and references	Intervention delivery, dosage	Materials and procedures	Tailoring and modifications	Main findings & authors' conclusions	Methodological quality
Cognitive defusion *Goal:* reducing distressing thoughts Maisel et al. (2019)	*Delivery:* Lab visit, face-to-face *Dosage:* 5 minutes	*Defusion condition* - Educated thoughts cause anxiety. Instructed to say "milk" out loud, noting perceptual qualities and repeat "milk" quickly for 30s and to "notice what happens." After 10-20s experimenter instructed to speak "louder" and "faster." Participants informed skill can be used for reducing distressing thoughts. Repeated exercise with their targeted thought.	Participants identify anxiety provoking thought ("I'm ugly") – Then re-stated thought as one word ("ugly").	AS higher trait levels of cognitive fusion than NT. Intervention significantly reduced thought discomfort/ believability with medium to large ES.	**Strong (82%):** Sampling strategy and participant characteristics sufficiently described. Randomisation reported but procedure not described. No blinding of participants and investigators. Estimates of variance provided.
Frontal/Executive program (FEP) *Goal:* cognitive and social functioning Miyajima et al. (2016)	*Delivery:* Sessions with therapist; individual *Dosage:* 44x1hr (2 p/wk) 22 wks (=44 hrs)	Modules; cognitive flexibility, working memory and planning - focusing on eye movement, perception, organisation of information, fine motor movement. Therapist encouraged participant to verbalise problem-solving and provided instruction on effective strategies. Training involved tokens/fine hand movements.	None described	Treatment group significantly better cognitive functioning, sequencing, verbal fluency, social functioning. Self-efficacy not improved. ES NR.	**Good (71%):** Sampling strategy/randomisation procedure incompletely described. Blinding not reported. Analytic methods described. Data insufficient to assess sample size.
Social-cognitive training (SCOTT) *Goal:* Improve social-cognitive performance and induce functional and structural plasticity in pre-frontal regions Rosenblau et al. (2020)	*Delivery:* online-based computer program; individual *Dosage:* a minimum of 3 hr per week, for 12 weeks Average 26.94±13.9 hr in total	Three game-like modules combined with rewards and jokers to train basic and complex emotion recognition of 40 preselected emotions. Structured information includes the emotion library booklet for self-study and task-based hints. Participants received individual feedback on their weekly training efforts and progress.	Three levels of difficulty with respect to the number of stimuli per task item, complexity of emotions, similarity of distractor items; self-paced	A significant improvement on the FP-explicit ($\eta^2_{partial}$ = 0.157) but not FP-implicit in SCOTT. SCOTT participants significantly improvement in inference of emotions and intentions ($\eta^2_{partial}$ = 0.142). SCOTT showed significant decreases in activity in the posterior cingulate cortex expending to the precuneus cortex compared to the control group. SCOTT showed significant increases in cortical thickness in the middle frontal gyrus region.	**Strong (82%):** Sampling strategy limited. Participant characteristics sufficiently described. Randomisation procedure clearly reported. No blinding of data collectors and participants. Estimates of variance provided. Effect size reported.
Exposure response prevention-based CBT (ERP-CBT) *Goal:* Reduce OCD Russell et al. (2013)	*Delivery:* Group; by psychologists -CBT/OCD trained. *Dosage:* Up to 20 sessions (1 hr). Average 17.43±4.3	Standard ERP-CBT for OCD adapted. Treatment rationale presented to participants. Visual tools and concrete/special interest related analogies used to convey psychological concepts. Structured and therapist-directed approach to sessional and homework content.	Optional educational sessions about understanding and rating anxiety can be provided	Both reduced OCD significantly. CBT large ES (d=1.01), larger than anxiety management. Self-rated improvement (d=0.33). No significant group difference.	**Strong (93%):** Sampling strategy/Participant characteristics/ Randomisation reported. Blinded assessors, no participant blinding. Estimates of variance provided. Power analysis/Effect size reported.

Table 3 (continued)

Intervention, goal and references	Intervention delivery, dosage	Materials and procedures	Tailoring and modifications	Main findings & authors' conclusions	Methodological quality
Mindfulness-based therapy (MBT-AS) Goal: depression, anxiety, rumination Spek et al. (2013)	Delivery: Groups 10-11; 2 trained psychologists. Dosage: 9 wk 2.5 hr. Home daily 58.5-76.5 hr total	Based on mindfulness cognitive therapy -cognitive elements/use of metaphors not included. Participants presented with intervention rationale/program content. Content: practicing breathing meditation, body scan, mindful eating and exercises. Instruction book Spek (2010).	Dosage – home activity daily 40 to 60 minutes	MBT-AS significantly reduced anxiety, depression, rumination; improved positive affect-treatment group vs control ($p<0.05$). ES large ($d=0.76$-1.25).	**Strong (82%)**: Sampling/ Participant characteristics described. Randomisation reported/procedure described. No blinding. Estimates of variance provided. Insufficient data to assess sample size.
MindChip (MC) Goal: Social emotional outcomes Tang et al. (2020)	Delivery: telehealth via Zoom Video communication facilitated by a psychologist Dosage: 1 hr/wk telehealth meeting for 10 wks; use the program for 10 hrs over 10 wks	Four learning tools: 1) a computer microchip containing modules pertaining to emotion recognition clues; 2) Mind Reading Toolbox with four different strategies or tools to support problem solving social emotional situations; 3) Mind Reading Lightbulb, a five step reflective process on the influence of behaviours on emotions based on CBT; 4) actional planning completed weekly. Participant were provided with a copy of Mind Reading program and a workbook (paper and electronic copies).	Action plan is divided into four main levels of difficulty, providing options for selecting goals based on the participants' level of comfort or social emotional level.	Significant group by time point was only observed for distant generalisation measure (partial $\eta^2 = 0.23$), with MC group demonstrating greater improvement in distant generalisation skills from baseline to post-intervention ($p<0.01$). Depression and anxiety outcomes did not reveal a significant main effect over time.	**Strong (82%)**: Sampling/ Participant characteristics described. Randomisation reported/procedure described. No blinding. Estimates of variance provided. Effect size reported.

Interventions for independent living skills

Intervention, goal and references	Intervention delivery, dosage	Materials and procedures	Tailoring and modifications	Main findings & authors' conclusions	Methodological quality
Virtual Reality Driving Simulation training (VRSDST) Goal: Improves ASD driving performance Cox et al. (2017)	Delivery: Driver simulation screen with trainer face-to-face in clinic Dosage: 8-12, 1-hour sessions (depending on participant progression)	Standard VRDST: EF driving deficits identified and tactical driving skills. Trainer demonstrated then monitored participant. Automated VRDST: Standard VRDST but only simulator's computerized voice provided feedback (e.g., "too fast") instead of trainer. Eye-tracking VRDST: eye-tracking into Standard VRDST. Videos of eye-view while driving re-placed trainer demonstration. Where participant should look while driving modelled.	Randomized to routine training (RT) or one of three types of VRDST (8–12 sessions).	VRDST significantly improved driving and EF performance over RT. General tactical composite: Standard and Automated VRDST superior to RT. VRDST not associated with greater improvement on EF than RT ($p=0.36$).	**Adequate (68%)**: Sampling strategy and participant characteristics limited. Randomisation reported but procedure not described. Blinding of participants and investigators not reported. Estimates of variance provided. Insufficient data to assess sample size.

Vocational Rehabilitation Outcome Interventions

Within the included studies, 10 studies reported on vocational rehabilitation interventions (see Table 3). Six studies aimed to improve interview skills (Hayes et al., 2015; Kumazaki et al., 2019; Kumazaki et al., 2017; Morgan et al., 2014; Smith et al., 2014; Strickland et al., 2013), with four studies focusing on improving employment performance and outcomes (Gentry et al., 2015; Wehman et al., 2017; Wehman et al., 2014; Wehman et al., 2020). The most available evidence for vocational rehabilitation interventions was Project SEARCH Plus ASD Supports (Wehman et al., 2017; Wehman et al., 2014; Wehman et al., 2020). Most studies used some form of technology to deliver the intervention (i.e., web- or app-based intervention tool) with four interventions using a face-to-face group delivery component (Morgan et al., 2014; Wehman et al., 2017; Wehman et al., 2014; Wehman et al., 2020).

Three of the six studies aiming to improve interview skills reported significant improvement with large effect sizes (Morgan et al., 2014; Smith et al., 2014; Strickland et al., 2013). Hayes et al. (2015) also reported significant improvement without reporting effect size and Kumazaki et al. (2019); Kumazaki et al. (2017) reported mixed results.

Findings were mixed for the four studies targeting employment performance and outcomes. Gentry et al. (2015) reported functional performance between groups was not significant. Wehman et al. (2014) reported a significant difference in the number of participants who attained employment, but no significant differences in wages or need for employment supports were found. By contrast, Wehman et al. (2017) reported significant large differences between groups for employment attainment, wages, hours worked and supports needed and Wehman et al. (2020) reported a significant difference in employment, with wages at or above minimum wage after 1 year.

Cognitive Skills Training Interventions

Eleven of the included studies evaluated cognitive training interventions (see Table 3). Four focused on reducing comorbid symptoms (Capriola-Hall et al., 2020; Gaigg et al., 2020; Russell et al., 2013; Spek et al., 2013), three focused on improving cognitive and social functioning (Miyajima et al., 2016; Rosenblau et al., 2020; Tang et al., 2020), one on improving QoL or social emotional outcomes (Hesselmark et al., 2014; Tang et al., 2020), one on core cognitive and social cognitive outcomes with employment as a secondary outcome (Eack et al., 2018), one on adjustment to college (White et al., 2019), and one on reducing distressing thoughts (Maisel et al., 2019). Most studies reported significant improvements following cognitive training intervention. Three studies (Eack et al., 2018; Gaigg et al., 2020; Spek et al., 2013; White et al., 2019) reported significant large intervention effects. Hesselmark et al. (2014) reported significant moderate effects

for improving QoL. Miyajima et al. (2016) and Rosenblau et al. (2020) found improvements in cognitive and social functioning. However, no effect sizes were reported in Miyajima et al. (2016). Maisel et al. (2019) reported a significant reduction in thought believability after intervention with medium to large effect sizes. Russell et al. (2013) reported a significant reduction in OCD symptoms with small to large effect sizes. However, cognitive training was not found to be significantly different when compared to anxiety management. Capriola-Hall et al. (2020) and Tang et al. (2020) reported mixed results.

Independent Living Skills Interventions

One study (Cox et al., 2017) used intervention to improve independent living skills. Cox et al. (2017) used a Virtual Reality Driving Simulation Training (VRDST) program to improve driving performance. Participants were allocated one of three types of VRDST or routine training. VRDST was found to significantly improve driving skills compared to routine training (see Table 3).

Methodological Quality Assessment

Of the 41 studies, 20 studies were rated as having 'strong' methodological quality and 18 studies were rated as having 'good' methodological quality (see Table 3 and Supplementary Table 2) using the Qualsyst critical appraisal tool (Kmet et al., 2004). The range in the rated methodological quality of the included studies was between 54% ('Adequate'; Bölte et al., 2002) and 93% ('Strong'; Garcia-Villamisar et al., 2016; Russell et al., 2013).

Of the 41 included studies, 34 described participant characteristics sufficiently and 19 studies reported the sampling strategy used clearly (see Table 3). However, two studies (Akabogu et al., 2019; Wijker et al., 2020) did not reported a between group comparison of participants' characteristics at baseline. All studies reported random allocation of participants. However, only 18 studies reported the procedure of randomisation. Most studies were at risk of observation bias due to a lack of blinding of assessors and/or interviewers. No study reported the blinding of participants and only 11 studies reported the blinding of investigators or assessors. Blinding, however, is inherently difficult in the type of intervention studies included in this review. Only three studies conducted a power analysis to determine the required sample size (Garcia-Villamisar et al., 2016; McVey et al., 2017; Russell et al., 2013). Twenty studies calculated and reported effect size regarding the effectiveness of the intervention. The rest of studies did not have sufficient information to assess the appropriateness of sample size or the effectiveness of the intervention.

Discussion

Interventions

This systematic review evaluated RCTs reporting on the effectiveness of non-pharmacological interventions for adults with autism. The 41 included studies were categorised into (1) social functioning and language skills interventions, (2) vocational rehabilitation outcomes, (3) cognitive training, and (4) independent living skills.

Our first main finding was that social skills interventions were the most frequently targeted interventions, followed by cognitive skills training and vocational rehabilitation interventions. This finding is similar to a previous systematic review of behavioural interventions for adaptive skill development in adults with ASD, which found social interaction skills were the most common intervention target (Palmen et al., 2012). This finding is also supported by a number of previous systematic reviews of psychosocial interventions using varying study designs for adults with autism (Bishop-Fitzpatrick et al., 2013) and of social skills interventions in young people and adults with autism (Ke et al., 2018). The finding that a relatively high number of interventions targeted social functioning is not surprising given that young adults with autism are more likely to be single, live with family members, and have ongoing social functioning difficulties compared with adults with other mental health disorders (Barneveld et al., 2014; Tobin et al., 2014).

Regarding the type of intervention designs, similar studies were grouped around themes arising from its content (e.g., vocational rehabilitation). However, many interventions, even those grouped in terms of treatment content differed in terms of breadth, where some targeted specific skills and others had broader outcomes. Moreover, while there were multiple interventions targeting social skills, only two interventions targeted language skills and one targeted independent living skills. This finding is of concern given that communication difficulties are a core and well documented difficulty among people with ASD (Magiati et al., 2014; Wise et al., 2019). Further research on interventions aiming to improve the language and communication skills and independent living skills of adults with ASD is critical, given that communication skills are crucial for social functioning and independent living skills are critical for quality of life and psychological wellbeing (Magiati et al., 2014; Wise et al., 2019).

Effectiveness

Two programs, PEERS for young adults and Project SEARCH plus ASD support, were identified to have the most robust evidence for improving social skills and employment outcomes, respectively. The effectiveness of the PEERS program was evaluated in four RCTs (Gantman et al., 2012; Laugeson et al., 2015; McVey et al., 2016; McVey et al., 2017), all which found significant improvement in primary outcomes and two of which reported medium to large effect sizes (Laugeson et al., 2015; McVey et al., 2016). Project SEARCH was evaluated in three RCTs (Wehman et al., 2017; Wehman et al., 2014; Wehman et al., 2020), which reported significant improvements on primary outcomes and one reported a large effect size (Wehman et al., 2017). Both programs were found to use standardised outcome measures adding to the rigour of these findings (Bolte & Diehl, 2013).

There were limitations to determining the effectiveness of existing non-pharmacological interventions for adults with ASD. Although there were some promising results from different studies in this systematic review, it is difficult to provide overall conclusions regarding the strength of treatments outside of the study context due to several factors. These factors include heterogeneity in intervention designs, outcome measures used and the methodological quality of the included studies. We were unable to conduct a meta-analysis as a result of these factors (Guolo & Varin, 2017).

Methodological Study Quality

Regarding methodological quality and study design, some of the studies included small sample sizes and results from these studies to be interpreted with caution. In terms of generalisation, participants in the studies may be relatively homogenous and not reflect the broader population of adults with ASD. The age ranges show that most studies included young adults, mainly in their 20s and early 30s. It should be noted that few studies involved adults with autism over the age of 60. The studies included in this review were also exclusively from economically advanced countries and mainly from the US or Europe, with a geographical exception of the studies conducted in Israeli (Saban-Bezalel & Mashal, 2015) and Japan (Kumazaki et al., 2019; Kumazaki et al., 2017; Miyajima et al., 2016). In summary, there are clear limitations in terms of generalising the findings both at the individual study level and considering the whole sample of studies included in this review.

There are also several points for consideration regarding the outcome measures used across the included studies. As reported by Bolte and Diehl (2013) and Brugha et al. (2015), we found a large variation in the outcome measures used across studies, with few outcome measures used across multiple studies. Furthermore, some outcome measures were not standardised and there was a tendency to not specify primary outcome measures, with a high number of outcome measures used across several studies. This use of outcome measures not only makes comparisons of studies difficult for evaluation and meta-analytic purposes (Brugha et al., 2015), but demonstrates a lack of consistency around outcome measure use in

adult autism intervention trials. Collectively, these findings suggest the need to establish guidelines for appropriate outcome measurement use in autism intervention trials (Bolte & Diehl, 2013). The heterogeneity of the studies and the outcome measures used in this review made it impossible to conduct a meta-analysis, which calls for comparisons using a random-effects model framework, an analytical approach that requires a substantial number of similar studies to make warranted inferences (Guolo & Varin, 2017).

Limitations

The current study underwent a rigorous review process by searching relevant electronic databases, comprehensively screening titles, abstracts and articles by two independent reviewers, and ensuring good inter-rater reliability agreement for Qualsyst methodological quality ratings. Despite good rater agreement, this systematic review is subject to limitations. No meta-analyses could be conducted due methodological shortcomings in the included studies according to the Qualsyst ratings and a large variety in intervention designs and outcome measures. As a result, only preliminary conclusions could be made about the effectiveness of non-pharmacological interventions in adults with autism.

Conclusion

In conclusion, 41 non-pharmacological studies were identified in this review. Most studies reported on social skills training, followed by cognitive skills training and vocational rehabilitation interventions. Two interventions, PEERS and Project SEARCH, showed the most robust evidence on effectiveness.

Due to heterogeneity in intervention designs, outcome measures and methodological quality of the included studies, no meta-analysis could be performed. While emerging evidence suggests that non-pharmacological interventions could be effective, there is an urgent need to establish guidelines around the use of outcome measures in these trials and for more RCT interventions aiming to improve communication and independent living skills of adults with ASD.

Declarations

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