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ORIGINAL PAPER

Meta-Analysis of RCTs of Technology-Assisted Parent-Mediated Interventions for Children with ASD

Hong Ji Pi[1] · Kannan Kallapiran[2,8] · Shashidhara Munivenkatappa[3] · Preeti Kandasamy[4] · Richard Kirubakaran[5] · Paul Russell[6] · Valsamma Eapen[7]

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Abstract

Technology-assisted parent-mediated interventions improve accessibility and are acceptable but not proven to be effective. We conducted a systematic search of 6 databases. We included and analysed results from studies on social and communication outcomes. Sixteen Randomised-Controlled-Trials (RCTs) with 748 participants were included. Most studies were rated as of good quality. Meta-analysis suggested that interventions were probably effective in improving emotion recognition. No significant differences were found in social communication, social functioning or language outcomes. At present, isolated tech interventions do not fulfil criteria for promising or established evidence-based interventions for ASD. Future research needs to focus on improving the effectiveness of technology-assisted parent-mediated interventions for ASD. Prospero Registration Number: CRD42020162825.

Keywords Online · Telehealth · Remote · Caregiver · Autism · ASD

Introduction

Autism Spectrum Disorder (ASD) is characterised by poor social communication, repetitive behavior or stereotypes, and sensory issues (APA, 2013). There has been an increase in the prevalence of ASD over the last few decades which could be related to a variety of factors (Rice et al., 2012). Global prevalence is estimated to be 0.5–1% (Baxter et al., 2015; Elsabbagh et al., 2012). Early intensive behavioral intervention by a therapist has been found to be beneficial (Reichow et al., 2014). However, a majority of children with ASD live in resource-poor settings in South Asia and other low and middle-income countries (Rahman et al., 2016) where there is a lack of evidence-based interventions tailored for those settings and a huge shortage of therapists (Patel et al., 2013). Access to care for childhood mental health disorders has been recognised as one of the major challenges (Collins et al., 2011). Parent training programs are one way of increasing access to interventions for ASD (Wainer & Ingersoll, 2015). Parent-mediated intervention has also been found to improve outcomes in ASD (Pickles et al., 2016). Cochrane review by Oono and colleagues indicated that parent-mediated intervention can lead to positive changes in parent–child interaction, improvement in child language comprehension, reduction in ASD characteristics, maternal knowledge about ASD, and maternal communication (Oono et al., 2013). A high-quality Randomised Control Trial (RCT) for parent-mediated intervention for ASD in south Asia, (Rahman et al., 2016) adapted the Preschool Autism Communication Trial (PACT) (Pickles et al., 2016) for local culture and delivery by trained lay health workers. They found that it improved parent–child synchrony and child-initiated communication with the parent but reduced mutual attention at the end of six months compared to treatment as usual. However, parents living far away from the

✉ Kannan Kallapiran
sgkkan@gmail.com

1 Darling Downs Health Service, The Toowoomba Hospital, Toowoomba, QLD, Australia

2 Gold Coast Health Service, Gold Coast, QLD, Australia

3 AIIMS Mangalagiri, Mangalagiri, Andhra Pradesh, India

4 JIMPER, Puducherry, India

5 Prof BV Moses Center for Evidence-Informed Health Care and Health Policy, Vellore, India

6 Christian Medical College, Vellore, India

7 UNSW, Sydney, Australia

8 Southport Health Precinct, 16-30 High Street, Gold Coast, QLD 4215, Australia

main centres can have difficulty accessing 12 sessions for PASS interventions. Other researchers have also found a shortage of professionals, limitations in finances, transportation, child care, waitlist, and time commitment as important barriers for widespread dissemination of parent-mediated interventions (Meadan & Daczewitz, 2015; Stahmer & Gist, 2001; Symon, 2001; Wainer & Ingersoll, 2015).

Literature Review

Technology-based interventions can potentially improve access to evidence-based treatments, at convenient times, with reduced costs (Baggett et al., 2010; Gros et al., 2013). Therefore, it is worth exploring technology-assisted evidence-based parent-mediated interventions that can support parents remotely. A variety of technological aids have been used to assist parents of children with ASD. They have varied from training programs for parents that are done remotely delivered using technology to others that used digital resources such as mobile apps, computer programs, DVDs, and robotic interventions that can be used by parents to engage their children with ASD (Aresti-Bartolome & Garcia-Zapirain, 2014; Grynszpan et al., 2014).

A review of tele-practice, for assessment and treatment of individuals with ASD, included eight studies with case series or ABAB designs (Boisvert et al., 2010). A meta-analysis included the use of technology-based interventions such as desktop computers, interactive DVD, and virtual reality for children with ASD. It included 22 studies that had group pre-post design, control studies, and RCTs. The ten RCTs included in this review had patients from the age of three to twenty-nine and focused on facial recognition, affect recognition, or emotional vocabulary. The individual studies in this study had different comparisons such as ASD patients with and without treatment, patients with ASD and no ASD or pre & post scores without any control arm. Combining the results for all of these studies, an effect size $d = 0.47$ with no significant difference related to IQ or age has been reported (Grynszpan et al., 2014). Knutsen et.al, included 36 articles predominantly pilot studies, single-case designs, case reports, surveys and, one RCT in their systematic review on telemedicine for ASD (Knutsen et al., 2016). They found that technology use was feasible and acceptable but recommended larger RCTs to better evaluate impact. In the systematic review on remotely delivered training for parent-mediated intervention for ASD, only interventions outside urban areas were included. They included seven trials (two pre-post cohorts, three that used multiple baselines and, two RCTs) that used self-guided websites with or without the support of therapists. Improvement in parent knowledge, intervention fidelity and child social communication skills was reported (Parsons et al., 2017).

Reviews focusing on a computer, app or robot-assisted interventions have reported promising results in a variety of developmental disorders and have shown to improve social, academic and intellectual functioning in ASD (DiPietro et al., 2019; Kokol et al., 2019). Ferguson et.al, focused exclusively on the use of telehealth training, supervision, or consultation of interventionists (professionals or parents) for delivery of Applied Behavior Analysis (ABA) therapy to individuals with ASD. They had 28 studies (where at least one person had ASD) of various designs of which only eight (28%) used a group design, all of which had a weak quality rating. More than 60% ($n = 17$) of studies rated positive improvements for all participants across all variables studied while 32% ($n = 9$) showed mixed efficacy. Some studies found improvement in the fidelity of delivery by the interventionists but no significant improvement in social communication behaviors in the participants (Ferguson et al., 2019).

Another meta-analysis included seven RCTs that used mobile apps for children with ASD. Their results suggested improved visual and fine motor skills in the intervention arm based on data from two RCTs but no significant benefits in social communication (Moon et al., 2019). Another systematic review evaluated the evidence for assessment, monitoring and treatment of all neurodevelopment disorders including ASD and ADHD. They included forty-seven trials of various designs and were interested in clinical effectiveness, economic impact and user impact while using various types of devices such as mobile apps/tablets, robots, gaming, computerized tests, videos, and virtual reality. About half of the studies reported positive effects (Valentine et al., 2020).

Though previous reviews have suggested that technology-assisted interventions for ASD are feasible and acceptable, their effectiveness has not been fully established (Ferguson et al., 2019; Grynszpan et al., 2014; Moon et al., 2019; Parsons et al., 2017). Previous reviews included fewer studies (Boisvert et al., 2010), poor quality studies (Knutsen et al., 2016), only studies from remote areas (Parsons et al., 2017), included all developmental disorders (Kokol et al., 2019; Valentine et al., 2020), based on only one type of intervention e.g. ABA (Ferguson et al., 2019), or only mobile apps (Moon et al., 2019) or are old & combined results from studies with different designs, comparisons and outcomes together in their meta-analysis (Grynszpan et al., 2014).

Study Aim

This meta-analysis aimed to examine the effectiveness of technology-based interventions in assisting parents to deliver interventions for their children with ASD based only on RCTs. The focus was on social communication and interaction as they are generally targeted and improve with parent-mediated interventions (Oono et al., 2013; Pickles et al., 2016). Parent-mediated interventions generally do not

focus on restricted and repetitive behaviors and hence that was not an outcome of interest for this review. As parental involvement and effectiveness are likely to be lesser with adolescents than with children, this study was limited to children 12 years or less. To our knowledge, there was no meta-analysis exclusively on RCTs of technology-assisted interventions supporting parents in delivering ASD-based interventions in children and focusing on social communication outcomes. This study aimed to explore the effectiveness of various evidence-based (RCT) technology-assisted, parent-mediated interventions for children with ASD on social and communication-related outcomes.

Method

The protocol was registered in the International Prospective Register of Systematic Review Protocols, PROSPERO number: CRD42020162825.

We conducted a systematic search in 6 databases: (1) MEDLINE, (2) EMBASE, (3) Cumulative Index to Nursing and Allied Health Literature (CINAHL), (4) Education Resources Information Center (ERIC), (5) PsycINFO, and (6) Pubmed in February 2020 and updated the search in January 2021. No date range was used for search.

A systematic search strategy was created for the followingterms "Autism", "ASD", "Telehealth", "Telemedicine" and "Randomised Controlled Trial" firstly for MEDLINE and then adapted it accordingly to each database. Search terms for parent or caregivers were left out as including them significantly reduced the number of studies and left out several studies that met the inclusion criteria for this review. The detailed search strategy used for different databases is presented in appendix 1. After the removal of duplicates, identified studies were shortlisted through screening of the title and abstract. Full texts of shortlisted studies were independently reviewed by two reviewers KK and HJ based on the inclusion and exclusion criteria mentioned below. References from included studies and past systematic reviews on this topic were hand searched to check if any additional studies met the inclusion criteria for this review.

Inclusion Criteria

(1) Randomized Controlled Trials with either a control intervention or waiting-list control group;
(2) Children were diagnosed with ASD according to DSM-5; with autism, Asperger's syndrome, or pervasive developmental disorders not otherwise specified using DSM-IV criteria; or diagnosed with Childhood autism, atypical autism or Asperger syndrome under ICD-10 criteria.
(3) Studies were included if:
    (i) the children with ASD were aged twelve years or less;
    (ii) where studies included children over twelve years, the proportion of such children was under 50% of cases.
(4) Studies included technology-assisted parent-mediated interventions;
(5) The technology employed could include mobile apps, DVD, video conferencing, web-based interventions, virtual reality, robots, or others;
(6) Social behavior and communication outcomes for the child were assessed;
(7) Studies were published in English.

Exclusion Criteria

(1) Interventions delivered by clinicians or others (except parents or caregivers);
(2) Studies with only face to face interventions;
(3) Studies using a single-subject multiple baselines;
(4) Studies that do not report any social or communication outcomes for the child;
(5) Interventions delivered in schools or specialist centers.

Disagreements on the inclusion between the two reviewers (KK and HJP) were resolved by discussions with co-author PK. Data from the included studies were extracted independently by one of the authors (KK, HJ, SM) using a prepared proforma (Appendix 2) and was then verified by another author. The differences were resolved by further discussion to reach a consensus. Mean (SD) and total sample size in each arm from validated measures and subscales were extracted. To determine the treatment effect Mean Difference (MD) and Standardized Mean Difference (SMD) along with 95% Confidence Interval (95% CI) were applied depending on whether the outcome measurements were made with the same assessment tool or different assessment tools respectively. For dichotomous data number of events and number randomized in each group were extracted. Risk Ratio (RR) along with 95% Confidence Interval (95% CI) was used as the effect measure. Analysis was conducted by following the guidance from the Cochrane handbook of systematic review (Higgins JPT, 2019). Data analysis was conducted using Revman 5.3 (2014).

Mantel Hansel method for dichotomous and inverse variance method for continuous data was employed with random effects model in calculating the pooled estimate. Heterogeneity was assessed with the Cochrane Q test along with I^2 statistics. An I^2 statistics range from 0 to 100%. An I^2 index less than 25% is indicative of low heterogeneity, between 25 and 75% represents average heterogeneity, and more than 75% means that considerable heterogeneity is present

(Higgins et al., 2003). Subgroup analyses were undertaken for studies reporting endpoint score (final measurement outcomes) and change in score values (changes from baseline) separately when different scales were used for measuring the same outcome.

Quality Assessment

The quality of studies included in this review was assessed based on the standards set by Reichow et al. (Reichow et al., 2008). They set up primary indicators (factors that relate to the validity of the study) and secondary indicators (other important factors). We followed their guidelines to rate each of the primary indicators as high (H), adequate (A), or inadequate (U) based on defined criteria. The secondary indicators were either positive (+) or negative (−) (Reichow, 2011). Furthermore, based on the number of primary and secondary indicators applicable, the studies were categorized into strong, adequate, or weak in overall quality. Strong ratings were offered for those studies if they scored high for all the primary indicators and at least four of the secondary indicators. Those studies with a high rating for a minimum of four primary indicators and two secondary indicators were rated as having adequate quality.

The weak rating was reserved for studies that had less than four high ratings for primary indicators and two secondary indicators. One of the three authors (KK, HJ, or SM) rated the quality of each of the included studies, and then it was verified by one of the other authors. Whenever there was a difference of opinion it was resolved by consensus or further discussion with PK. Only 6.25% (N = 1) of the articles required verification by another author to resolve differences in opinion. As we had less than ten studies in each of the analyses we were unable to check for publication bias using a funnel plot.

Results

A total of 16 studies (thus K = 16; n = 786) that fulfilled the inclusion criteria were included. The PRISMA flowchart is depicted in Fig. 1. The studies were mostly conducted in the developed world, eight in the United States, and four in Australia, one each in United Kingdom, Italy, Macedonia, and Israel. There was variability in the age ranges included in the studies, eight studies included participants under the age of six (Esposito et al., 2017; Fletcher-Watson et al., 2016a; Ibañez et al., 2018; Ingersoll et al., 2016; Lindgren et al., 2020; Parsons et al., 2019; Vismara et al., 2016; Whitehouse et al., 2017) another five included those 12 or under (Beaumont, 2018; Gev et al., 2017; Voss et al., 2019; Williams et al., 2012; Young & Posselt, 2012). We also included three other studies, as more than 80% of their participants were under twelve or had a mean age less than twelve (Kelly, 2017; Vasilevska Petrovska & Trajkovski, 2019; Vasquez-Terry, 2014). Two of them were included in the analyses (Vasilevska Petrovska & Trajkovski, 2019; Vasquez-Terry, 2014). The details of the included studies are summarised in Table 1.

Parent Characteristics and Involvement

Amongst studies that used app-based interventions two reported basic English proficiency (Fletcher-Watson et al., 2016b; Vasquez-Terry, 2013), one study enrolled parents who had a university degree (Esposito et al., 2017) and one study had 20% parents in high socioeconomic status (SES), 60% in middle and 20% in the bottom (Fletcher-Watson et al., 2016b). Others did not report information regarding gender of the parent, age, education, or socio-economic status. Parent training varied from initial training at the beginning of the program (Esposito et al., 2017; Parsons et al., 2019; Whitehouse et al., 2017) to ongoing weekly training (Vasquez-Terry, 2013) or brief instruction document on how to run the activities (Fletcher-Watson et al., 2016a). The involvement of parents was mostly to facilitate the activities and play a supportive role.

In the online group, studies reported that parents with proficiency in English (Ibañez et al., 2018; Ingersoll et al., 2016; Vismara et al., 2018), three reported on level of education (Ibañez et al., 2018; Ingersoll et al., 2016; Vismara et al., 2018) and forty to sixty percent had either college or graduate education and in one trial that reported income levels about 40% earned an annual income of more than 75 thousand US dollars (Vismara et al., 2018). Most studies in this group offered substantial training to the parents in the form of web-based tutorials (Ibañez et al., 2018), coaching (Lindgren et al., 2020) technical support, or ongoing therapist assistance (Ingersoll et al., 2016), and additional website resources (Vismara et al., 2018). Parents also played a more active role in the implementation of the intervention, offered reinforcement for positive engagement of the child, and collected outcome data.

Of the three studies that used DVD-based interventions, one study investigated and found no additional benefit from parental involvement. They included English-speaking and non-English speaking parents (Gev et al., 2017). Generally, parents in the DVD and computer-based interventions groups only played a supportive role in helping their child's engagement with the intervention.

Quality of Studies

The quality of studies was rated using the criteria by Reichow and detailed in Table 2 (Reichow, 2011). Six studies were rated strong, 10 were rated adequate and 1 study

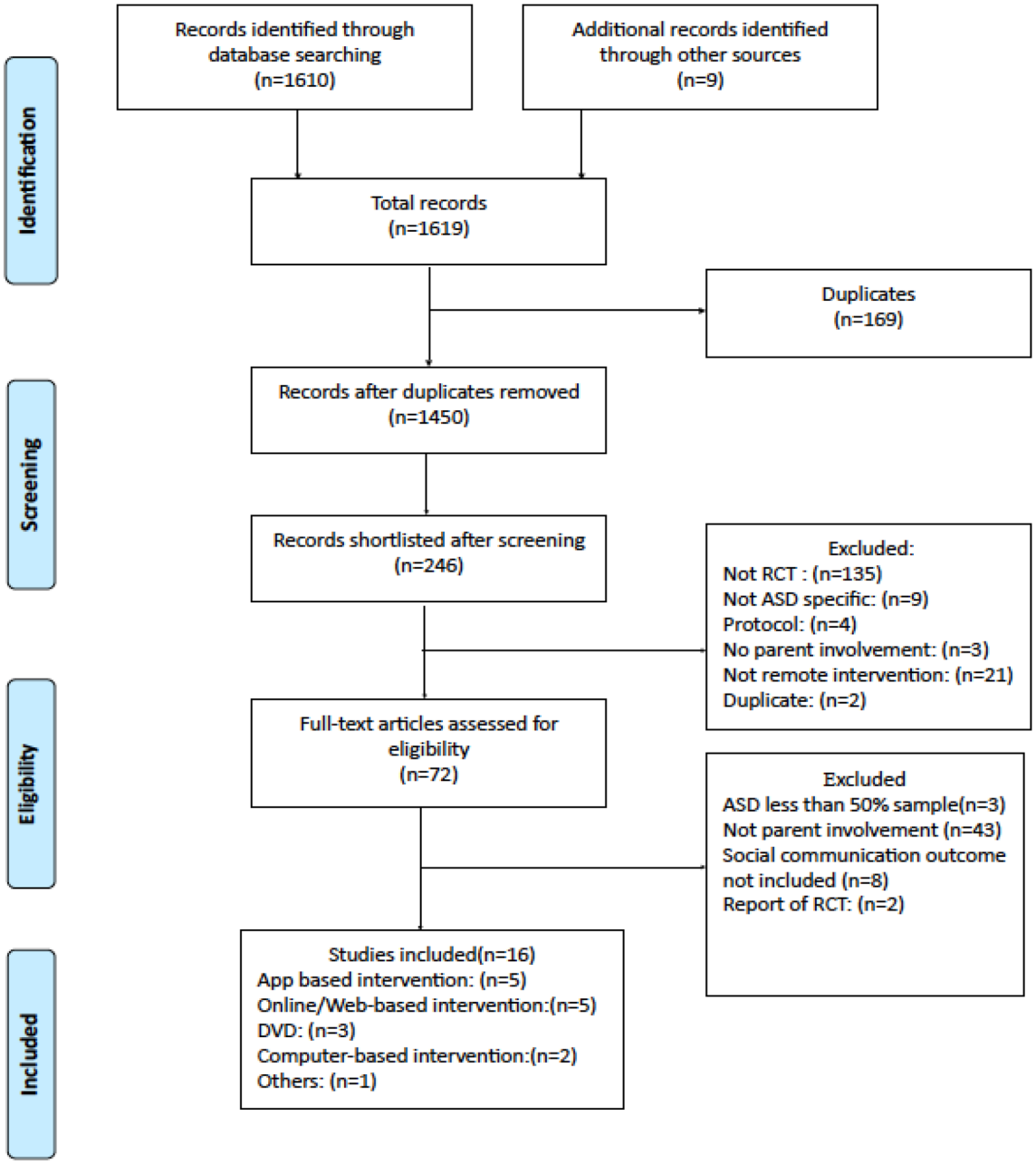


Fig. 1 PRISMA flow chart

whose abstract only was available was rated weak in overall quality. Several studies had all primary indicators but only a few studies had blind raters (Fletcher-Watson et al., 2016a; Vasquez-Terry, 2014; Vismara et al., 2016; Voss et al., 2019) and only six studies had social validity (Ingersoll et al., 2016; Lindgren et al., 2020; Vasquez-Terry, 2014; Vismara et al., 2016; Williams et al., 2012; Young & Posselt, 2012).

Outcome Measures

The details of the various measures used in the trials have been summarized in Appendix 3.

Effectiveness

One of the studies (Ibañez et al., 2018) used a Bayesian distribution which led to skewed results compared to all the other studies. Including data from this study changed the

Table 1 Characteristics of included studies

Study ID	Sample	Intervention	Control	Outcomes	Results
App based interventions					
Esposito (2017)	Parents of children with ASD mean age 47 months, male 90%. (n = 30) Italy	Intervention: Tablet application: 30 min per day (attention, vocabulary, and imitation) × 4 weeks and TAU (ABA 6 h per week) Prior to the experiment, parents were trained for 1 h and could contact the project staff throughout the training(n = 15)	Control: Only ABA 6 h. per week (n = 15)	Post treatment (4 weeks) Game scores across each domain (attention, vocabulary, and imitation)	Post treatment (4 weeks) trend favored intention arm (for attention, imitation, and receptive language) but not statistically significant
Fletcher-Watson (2016a)	Parents of children with ASD < 6 years, male 80%. (n = 54) United Kingdom	Intervention: Find me app. 5 min per day or 10 min every other day for two months through iPad and TAU (Integrated mainstream classes or special units) average 11.5 h per week (n = 27)	Control: TAU (Integrated mainstream classes or special units) average 11.5 h per week (n = 27) 2 had down syndrome	Post treatment (2 months) and 6 months follow up ADOS BOSCC MCDI CSBS MSEL	Post treatment and 6 months follow up. No significant difference Satisfaction: More than 90% children, mothers liked the app and found it simple to use
Parsons (2019)	Parents of children with ASD aged 2–6 years, male 81%. Outside metro (n = 59) Australia	Intervention: TOBY APP (4 major syllabuses: visual motor, imitation, language & social)20 min per day for 3 months supported by parent or guardian Modes of delivery: (1) Solo, (2) Parent/caregivers (3) NET Researchers stepped in only if participants requested technical support (n = 30)	Control: Waitlist offered APP after the end of the treatment phase at 3 months (n = 29)	Post treatment (12 weeks) & 3 months follow up Primary measures MSEL Symbolic play CSBS Secondary measures: POM TOP	Post treatment (12 weeks): Average intervention only 11 min /day. Expressive speech domain (MSEL) was significantly improved in the intervention arm No differences in other domains of MSEL, SPT and CSBS, TOP & POM *Bonferroni correction was not done Follow up (3 months post treatment): Pooled data (including waitlist controls) only reported High dropout rate n = 13 indicates poor adherenc
Vasquez (2014)	Parents of children with ASD aged 3–23 years, male 80% (n = 86) United States	Intervention I: App academy web-based Rx training program (n = 30) Intervention II: App academy and group intervention (n = 30)	Control: Used iPad as an assistive technology device. No formal training(n = 26)	Post treatment (6 weeks) FES PEI TARF-R ATEC	Post treatment (6 weeks) Non-significant increases in social communication and language total scores compared to control arm but not family empowerment

Table 1 (continued)

Study ID	Sample	Intervention	Control	Outcomes	Results
Whitehouse (2017)	Parents of children with ASD mean age: 40 months, male 80%, (n = 80) Australia	Intervention: TOBY Application (Syllabus: visual motor, imitation, language & social) 20 min per day for 6 months supported by parent or guardian Modes of delivery:1) Solo,2) Parent/caregivers 3) NET. Study team called the caregiver fortnightly for support (n = 41)	Control: TAU -were able to access community-based therapy but not informed to download any applications Also received loan iPad (n = 39)	Post treatment (3 months) and follow up 3 months post treatment Primary outcome ATEC Secondary outcome MSEL VABS II Tertiary outcome MCDI CSBS RBS-R	Post treatment (3 months) No significant difference in ATEC scores. Better visual reception & fine motor on MSEL not on language domains Better on MCDI total words understood scale but not on others Follow up (3 months post treatment) No significant change at follow up for the MSEL or VABS-II scales Intervention fidelity: 19 min / day in first 3 months 2 min/ day for second 3 months
Online/web based					
Ibanez (2018)	Parents of children with ASD aged 18 to 60 months. Mothers (94) Fathers (10). Male 84%. (n = 104) United States	Intervention: Web based tutorial (enhancing Interactions) Content (3 main sections): Introduction, daily routines & toolbox—evidence based strategies. Encouraged to review material across 4–5 sessions with approximate completion time 6 h. Parents allowed access even after the program finished at month end. (n = 52)	Control: Waitlist. Complete at own pace. Control group got free access to tutorial at the end of the survey (n = 52)	Post treatment and 1 month follow up Parent behavior survey Child behavior survey PES PIA- CV PSI-SF SUS USQ	Post treatment and month follow up Parent use of strategies, child engagement, social relatedness and nonverbal behavior significantly better in the intervention arm both at post treatment and follow up Parental self-efficacy & parent child dysfunctional interaction subscale of PSI were only better for tutorial arm at follow up Tutorial parents indicated high levels of satisfaction. Limitations: self-report measures used & 21% data missing

Table 1 (continued)

Study ID	Sample	Intervention	Control	Outcomes	Results
Ingersoll (2016)	Parent of children with ASD aged 19—73 months, male 76%. Mainly rural & or underserved areas (n = 27) United States	Intervention: Therapist assisted: Online website access 12 × 80 min. Manual, self-check quiz, homework plan, reflection questions, video resources, moderated forum and contact to staff via phone or email for assistance for technology only 2 × 30-min remote coaching sessions per week (Total: 24 sessions) through videoconferencing (n = 14)	Control: Self-directed learning: Online website access 12 × 80 min. Manual, self-check quiz, homework plan, reflection questions, video resources, moderated forum and contact to staff via phone or email for assistance for technology only (n = 13)	Post treatment (12 weeks) & 3 month follow up CEWFS CES-D Engagement Fidelity checklist Program satisfaction Therapist evaluation FIQ PSOC Child language targets MCDI VABS- II	Post treatment (12 weeks) & follow up 3 months later Parent self-efficacy—Both efficacious Parental stress—Both lesser Positive perception—Higher in therapist Child language targets—Improved in both at the end of treatment At follow up only the therapist assisted group was better in social skills. Better program engagement and completion in the therapist assisted group. Completion was associated with improved knowledge and fidelity
Lindgren (2020)	Parents of children with ASD aged 21–84 months male 84% n = 38. Unites States	Intervention: CT procedures conducted by parents (minimum 10–15 min per day) with coaching provided by behavioral consultants via tele-health (1 × 60 min session per week) n = 21	Control: Delay control (treatment as usual) n = 17	Post treatment (12 weeks) Primary outcome: Reduction in the frequency of child's problem behavior Secondary outcome: Increases in manding and developmentally appropriate tasks Parent's acceptability of FCT using the first item of TARF-R	Post treatment at (12 weeks) The proportion of children achieving at least an 80% reduction of problem behavior was significantly higher in the treatment group (100% vs. 12% respectively; $p < 0.0001$, two-tailed Fisher's exact test Children receiving FCT treatment showed significantly increased manding and developmental tasks Parents reported high levels of acceptance for FCT
Vasilevska Petrovska (2019)	Parents of children with ASD(ICD-10) 7 to 15 years old, male 71%. (n = 32) North Macedonia	Intervention: Ucime Emocii (learning Emotions) a cross platform web application designed for teaching and practicing emotion comprehension skills in children with ASC 24 to 48 session lasting 15 to 30 min over 8 weeks, for a total of 720 min screen time (n = 16)	Control: Standard school curriculum (n = 16)	1 week post treatment (9 weeks) Emotion Comprehension Test (ECT)	Post treatment (9 weeks): Significant improvement in Emotion understanding skills when compared to the control group Parental Satisfaction: Not reported

Table 1 (continued)

Study ID	Sample	Intervention	Control	Outcomes	Results
Vismara (2016)	Parents of children with ASD(ADOS) 18—48 months with. male 68% (n = 24) United States	Intervention: 12 weekly 1.5 h. videoconferencing session. P-ESDM. Plus, access to website esdmanywhere.org (n = 14) Therapist trained	Control: Monthly 1.5 h. videoconferencing plus website minus P-ESDM content (n = 10)	Post treatment (12 weeks) and 3 months follow up p-ESDM fidelity Website use Program satisfaction Social communication behaviors	Post treatment (12 weeks) Child outcomes -P-ESDM high rates of imitation. Not in language utterances or joint attention Therapist fidelity—80% or higher Parent satisfaction—high Parent fidelity- 5/14 in p-ESDM vs 2/8 3 months follow up Parent fidelity: 4 more in p-ESDM achieved fidelity. Females better than males
DVD					
Gev (2017)	Parents of children with high functioning ASD aged 4–7 male 80%, (n = 77) Israel	Arm 1. The Transporters (TT) animated series 10 min per day (2 sessions) × 8 weeks + Parent (activity guide with 12 emotion focused activities) Arm 2. The Transporters animated series 10 min per day (2 sessions). No parent activities	Arm 3. Charlie & Dodo animated series 10 min per day (2 sessions) × 8 weeks + Parent (activity guide with 12 emotion focused activities) Arm 4. The Transporters animated series 10 min per day (2 sessions). No parent activities	Post treatment (8 weeks) and at 3 months follow up: Emotional Recognition (ER)- 3 level computerized tasks Emotional Vocabulary (EV) Tasks	Post treatment (8 weeks) and at 3 months follow up. TT arms better than control arms. No significant effect of parental activities on either TT or control arms. Verbal ability and autism severity at baseline were significant covariates
Williams (2012)	Parents of children with ASD aged 4–7. Male Intervention 89% & controls 85.2% (n = 55) Australia	Intervention: The transporters animated and narrated television series (15 five-minute episodes portraying 15 key emotions) Mode of delivery: DVD Intervention: 15 min/day over 4 weeks (n = 28)	Control: Thomas the Tank Engine series five used to control time spent watching children's DVD Control (n = 27)	Post treatment (5 weeks) and 3 months post completion: Emotion identification and matching tasks Situation and desire-based mind reading tasks NEPSY-II affect recognition NEPSY-II TOM tasks	Post treatment (5 weeks): Emotion identification: significant effect identifying expression of anger and matching of emotions No significant effect for NEPSY-II affect recognition, mind reading and TOM tasks 3 months follow up: Identification of happiness and mind reading situational tasks improved from post treatment ax. But identification of anger and TOM contextual tasks decreased from post treatment Chronological age and VIQ positively influenced results

Table 1 (continued)

Study ID	Sample	Intervention	Control	Outcomes	Results
Young (2012)	Parents of children with ASD aged 4–8 years (n = 25) Australia	Intervention: The Transporters animated and narrated television series (15 five-to-ten-minute episodes portraying 15 key emotions) Mode of delivery: DVD Intervention: 15 min/day at least 3 episodes/ day over 3 weeks (n = 13)	Control: Thomas the Tank Engine Mode of delivery: DVD 3 episodes/day for 3 weeks Parents noted duration of Rx (n = 12)	Post treatment (3 weeks) Measures: NEPSY-II The Faces Task Parent SCQ	Post treatment (3 weeks) Significant improvement in emotion recognition No significant change in socialisation
Computer based interventions					
Kelly (2017)	Parents of children with High functioning ASD aged 8–14, male 100% (n = 27) United States	Social Express (Parent guided, computer mediated social skills training) and TAU (9 week social skills group for children and concurrent group for parents)	TAU- 9-week social skills group for children and concurrent group for parents)	Post treatment (9 weeks) BASC-II PRS BASC-II SRP PSI-SF ASDS SRS-II CPSES MSLSS	Post treatment (9 weeks): No significant effects on social skills, adaptive skills, internalizing problems, life satisfaction scores and parental stress
Beaumont (2018)	Parents of children with ASD aged 7–12 years (n = 70) Male—86% United States	Intervention: SAS computer game Parents: 150 min of group online and 10 weekly group online sessions	Control: Placebo CIA Parents: Online coaching academic spy themed games for 10 weeks	Post treatment:(10 weeks) ERSSQ-P SSQ-P ERSSQ-T	Post treatment (10 weeks): Parent report: improved emotion regulation and social skills Teacher-report: Trend for better social skills but not significant SAS participant greater improvement in anxiety management strategies ($p < 0.002$)
Others					
Voss (2019)	Parents of children with ASD aged aged 6–12 years, males = 89% (n = 71) United States	The Superpower Glass intervention, (worn by the child) and a smartphone app, which promotes facial engagement and emotion recognition by detecting facial expressions and providing reinforcing social cues. 20-min sessions at home 4 times per week for 6 weeks. (n = 40)	ABA therapy as usual for 6 weeks. (n = 31)	Post treatment (6 weeks) SRS-II VABS-II Socialization NEPSY-II Affect •Emotion guessing game (EGG)	Post treatment (6 weeks) Improvement seen on VABS-II but not significant No difference between cohorts on other outcome measures

ABA applied behavioral analysis, *ADIS P/C* anxiety disorders interview schedule for DSM-IV: parent and child version, *ADOS* autism diagnostic observation schedule, *ASDS* asperger syndrome diagnostic scale, *ASD* autism spectrum disorder, *ATEC* autism treatment evaluation checklist, *BASC-II-PRS* behavior assessment system for children-II parent rating scale, *BASC-II-SRP* behavior assessment system for children-II self report personality, *BOSCC* brief observation of social communication changes, *BPS* being a parent scale, *BS-R* repetitive behavior scale—revised, *CBCL* child behavior check list, *CES-D* center for epidemiological studies-depression scale, *CEWFS* computer-email-web fluency scale, *CIA* central intelligence agency, *CGAS* children's global assessment scale, *COMPASS* collaborative model for promoting competence and success, *CPSES* children's perceived self efficacy scale, *CSBS* communication symbolic behavior scales, *CSQ* consultation satisfaction questionnaire, *DAS* differential abilities scale, *DSM* diagnosis statistical manual, *ECBI* Eyberg child behavior inventory, *ECT* emotion comprehension test, *EIRP* early intervention research program, *ERSSQ-P* emotion regulation and social skills questionnaire-parent, *ERSSQ-T* emotion regulation and social skills questionnaire-teacher, *FES* family empowerment scale, *FF* face-to-face, *FIQ* family impact questionnaire, *GSRS* group session rating scale, *ID* intellectual disability, *IWT* interactive web training, *MCDI* MacArthur-Bates communication development inventory, *MSEL* Mullen scales for early learning, *MSLSS* multidimensional student life satisfaction survey, *NET* natural environmental training, *NEPSY-II* developmental neuropsychological assessment, second edition, *OWLS* oral and written language scales, *PEI* patient enabled instrument, *PES* parental efficacy scale, *PIA-CV* parent interview for autism -clinical review, *P-ESDM* parents in the early start denver model, *PET-GAS* psychometrically equivalence tested goal attainment scaling, *POM* pragmatic observation measure, *PSI* parental stress index, *PSOC* parent sense of competence scale, *SAS* secret agency society, *SCAS-C* spence children's anxiety scale child version, *SCAS-P* spence children's anxiety scale parent version, *SCQ* social communication questionnaire, *SPT* symbolic play test, *SRS-II* social responsiveness scale, second edition, *SSQ-P* social skills questionnaire-parent, *SUS* system usability scale, TARF-R treatment acceptability rating form-revised, *TAU* treatment as usual, *TOBY* therapy outcomes by you, *TOM* theory of mind, *TOP* test of playfulness, *TH* telehealth, *USQ* user satisfaction questionnaire, *VABS II* Vineland adaptive behavior scale, 2nd edition, *FCT* functional communication training, *FA* functional analysis, *TARF-R*Treatment Acceptability Rating Form-Revised

direction of the results. Hence, we decided to exclude that from the analysis. Four studies that used app based interventions, one that used online intervention, and one with interactive DVD-based intervention reported social communication outcomes. Most studies used parent-rated measures such as the Autism Treatment Evaluation Checklist (ATEC), Communication Symbolic Behavior Scales (CSBS), frequency of social behaviors, and peer interest, however, one study used therapist rated measure Brief Observation of Social Communication Changes (BOSCC) (Fig. 2). The technology-assisted parent-mediated interventions did not offer significantly greater benefits in social communication compared to controls (MD 0.75, 95% CI − 0.16 to 1.68; participants = 282; studies = 6; I2 = 39%) (Fig. 2) moderate certainty using Grading of Recommendations, Assessment, Development and Evaluations (GRADE) criteria (Table 3). Two studies (one that evaluated app-based intervention and the other one compared interactive DVD based intervention) used therapist rated Vineland Adaptive Behavior Scale (VABS) social skills sub-scale to measure socialization as a functional outcome. Based on data from these two studies that included 129 participants there was no significant difference between the two arms (MD 1.83, 95% CI − 2.01 to 5.68; $I^2 = 0\%$) (Fig. 3) moderate certainty using GRADE criteria (Table 3).

Emotion recognition was reported in three studies, one study that used an online intervention and two that used interactive DVD intervention, using two different parent-rated measures (Emotion Comprehension Test & NEPSY-II affect recognition). Though the treatment arm was significantly more effective than control (SMD 1.25, 95% CI 0.54–1.96; participants = 112; studies = 3; I2 = 63%) (Fig. 4) lack of blinded outcome assessment, significant heterogeneity and high risk of publication bias led to downgrading to very low certainty according to GRADE criteria (Table 3).

Four studies that used app-based interventions provided language outcomes as total scores, receptive language, gestures and expressive language scores. Across all four outcomes, language total score (MD − 0.06, 95% CI − 2.76 to 2.64; participants = 179; studies = 3; I2 = 43%); receptive language (MD 10.49, 95% CI − 13.11 to 34.09; participants = 177; studies = 3; I2 = 59%); gestures (MD 1.71, 95% CI − 1.24 to 4.66; participants = 129; studies = 2; I2 = 0%) and expressive speech (SMD 0.03, 95% CI − 0.36 to 0.42; participants = 102; studies = 2; I2 = 0%) there were no significant differences between the two arms with moderate certainty according to GRADE criteria (Table 3).

Publication Bias

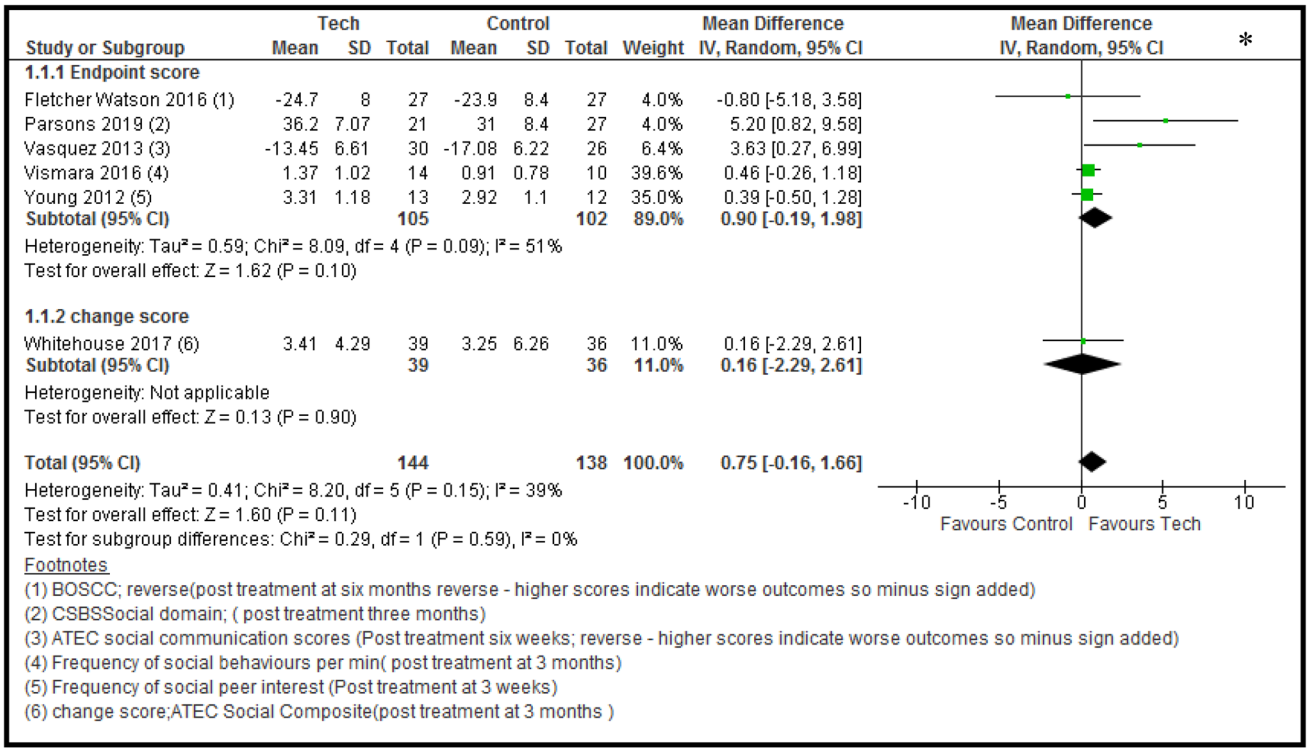
Due to a small number of trials in each comparison it was not possible to check for publication bias.

Table 2 Quality of studies included

Study	Primary indicators						Secondary indicators								
	Patient	Rx	Control	Outcome measures	LRQ	Statistics	Random	IOA	Blind raters	Fidelity	Attrition	Generalization	Effect size	Social validity	Quality summary
App based interventions															
Esposito (2017)	(H)	(H)	(H)	(H)	(H)	(H)	+	−	−	+	−	−	−	−	Adequate
Fletcher Watson (2016b)	(H)	(H)	(H)	(H)	(H)	(H)	+	+	+	+	+	+	−	−	Strong
Parsons (2019)	(H)	(H)	(H)	(H)	(H)	(H)	+	+	−	+	−	+	−	−	Adequate
Vasquez (2014)	(H)	(H)	(H)	(H)	(H)	(H)	+	−	+	+	+	−	−	+	Strong
Whitehouse (2017)	(H)	(H)	(H)	(H)	(H)	(H)	+	−	−	+	+	−	−	−	Adequate
Web/online interventions															
Ibanez (2018)	(H)	(H)	(H)	(A)	(H)	(H)	+	−	−	−	+	+	+	−	Adequate
Ingersoll (2016)	(H)	(H)	(H)	(H)	(H)	(H)	+	+	−	+	+	+	−	+	Strong
Vasilevska Petrovska (2019)	(H)	(H)	(H)	(H)	(H)	(H)	+	−	−	+	+	−	−	−	Adequate
Vismara (2016)	(H)	(H)	(H)	(H)	(H)	(H)	+	+	+	+	+	+	−	+	Strong
DVD interventions															
Gev (2016)	(H)	(H)	(H)	(H)	(H)	(H)	+	+	−	+	+	+	−	+	Strong
Williams (2012)	(H)	(H)	(H)	(H)	(H)	(H)	+	−	−	−	−	+	−	+	Adequate
Young (2012)	(H)	(H)	(H)	(H)	(H)	(H)	+	−	−	−	−	−	−	+	Adequate
Computer based interventions															
Kelly (2017)	(H)	(H)	(H)	(H)	(H)	(H)	+	−	−	+	+	−	−	−	Adequate
Beaumont (2018)	(H)	(H)	(H)	(H)	(H)	(H)	+	−	−	−	−	−	−	−	Weak
Other interventions															
Voss (2019)	(H)	(H)	(H)	(H)	(H)	(H)	+	−	+	+	−	−	−	−	Adequate
Lindgren (2020)	(H)	(H)	(H)	(H)	(H)	(H)	+	+	−	+	+	+	+	+	Strong

The secondary indicators were either positive (+) or negative (−)

Rx independent variable, *Control* comparison condition, *Outcome measures* dependent variable, *LRQ* link between research question and data analysis, *IOA* inter observer agreement, *H* high, *A* adequate, *U* inadequate



*size of mean differnce point indicates precision of results

Fig. 2 Forest plot of comparison 1 Tech assisted Versus Control outcome 1.1 social communication

Discussion

The focus of this review was to evaluate if technology-assisted parent-mediated interventions were effective in improving social communication outcomes for ASD. Unlike other systematic reviews (DiPietro et al., 2019; Ferguson et al., 2019; Grynszpan et al., 2014; Parsons et al., 2017) in this study, only randomized controlled trials were included. Sixteen studies with 748 participants were included in the narrative synthesis of this review. An increasing number of RCTs published on this topic in the last few years indicates the growing interest and importance of this area.

Similar to previous reviews (Aresti-Bartolome & Garcia-Zapirain, 2014), studies in this review used different technologies such as mobile apps, computer games, interactive DVD applications, online web-based interventions and superpower glass intervention with support of an app. Though a previous review (DiPietro et al., 2019) included robotic interventions, none of those studies had any parent involvement and many were conducted in schools, therapist's centre or research labs and hence not included in this review. Unlike previous meta-analyses that were interested in the impact on academics, the main focus of this review was the effect on social communication and interaction (Aspiranti et al., 2020). Hence RCTs that focused only on behavior (Hanrahan et al., 2020; Kuravackel et al., 2018; Turgeon & Lanovaz, 2019) anxiety (Conaughton et al., 2017) parental knowledge (Jang et al., 2012), parental stress (Marino et al., 2020), parent satisfaction (Fisher et al., 2014) or executive function (De Vries, 2015) were excluded.

This review supports previous research that suggests the feasibility and acceptability of technology-based interventions for ASD (Ferguson et al., 2019; Moon et al., 2019; Parsons et al., 2017). Further, studies included in our review showed that parents reported high levels of satisfaction with technology (Fletcher-Watson et al., 2016a; Ingersoll et al., 2016; Vismara et al., 2016). However, one of the app-based studies had significantly high rates of dropouts which merits further exploration (Parsons et al., 2019).

Data from a total of eight comparable studies could be combined in a meta-analysis. Analysis of six studies reporting social communication outcomes revealed no significant difference between intervention and control arms. A previous review that included only app-based interventions that combined data from two RCTs also had similar results. They found that fine motor and visual skills were improved in the intervention arm but no difference in speech, gestures, social communication, and symbolic play (Moon et al., 2019). Results from our analysis contrast with a previous meta-analysis where the effect size from 14 controlled

Table 3 Summary of findings—Tech assisted parent mediated intervention compared to Control for ASD

Outcomes	Anticipated absolute effects[i] (95% CI)		Relative effect (95% CI)	No. of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Risk with control	Risk with tech assisted parent mediated intervention				
Social communication	The mean social communication was 0	MD 0.75 higher (0.16 lower to 1.66 higher)	–	282 (6 RCTs)	⨁⨁⨁◯ MODERATE[a,b,c,d]	Tech assisted parent mediated intervention probably results in little to no difference in social communication
VABS social skills	The mean VABS social skills was 0	MD 1.83 higher (2.01 lower to 5.68 higher)	–	129 (2 RCTs)	⨁⨁⨁◯ MODERATE[a,c,d]	Tech assisted parent mediated intervention probably results in little to no difference in VABS social skills
Emotion recognition	–	SMD 1.25 higher (0.54 higher to 1.96 higher)	–	112 (3 RCTs)	⨁◯◯◯ VERY LOW[e,f,g]	The evidence is very uncertain about the effect of tech assisted parent mediated intervention on emotion recognition
Language total score	The mean language total score was 0	MD 0.06 lower (2.76 lower to 2.64 higher)	–	179 (3 RCTs)	⨁⨁⨁◯ MODERATE[a,c,d,h]	Tech assisted parent mediated intervention probably results in little to no difference in language total score
Receptive language	The mean receptive language was 0	MD 10.49 higher (13.11 lower to 34.09 higher)	–	177 (3 RCTs)	⨁⨁⨁◯ MODERATE[a,c,d,h]	Tech assisted parent mediated intervention probably results in little to no difference in receptive language
Gesture	The mean gesture was 0	MD 1.71 higher (1.24 lower to 4.66 higher)	–	129 (2 RCTs)	⨁⨁⨁◯ MODERATE[a,c,d]	Tech assisted parent mediated intervention probably results in little to no difference in gesture
Expressive	–	SMD 0.03 higher (0.36 lower to 0.42 higher)	–	102 (2 RCTs)	⨁⨁◯◯ LOW[a,c,d]	Tech assisted parent mediated intervention may result in little to no difference in expressive

GRADE working group grades of evidence. High certainty—We are very confident that the true effect lies close to that of the estimate of the effect. Moderate certainty—We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different. Low certainty—Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect. Very low certainty—We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

ASD patient or population, *Setting* home and other non-clinical settings, *Intervention* tech assisted parent mediated intervention, *Comparison* control, *CI* confidence interval, *MD* mean difference, *SMD* standardised mean difference

[a]Though most studies did not have blind outcome assessment, that did not appear to influence the outcomes as most studies reported negative results. Also, most studies were rated strong or adequate quality according to criteria by Reichow et.al

[b]Moderate heterogeneity but that can be explained by differences in sample population, intervention and controls hence rated not significant risk of heterogeneity

[c]Wide confidence interval with lower limit well below threshold for significant effect

[d]Publication bias could not be formally tested because of small number of studies. But most studies reported negative results. Hence publication bias unlikely to affect the confidence in the results

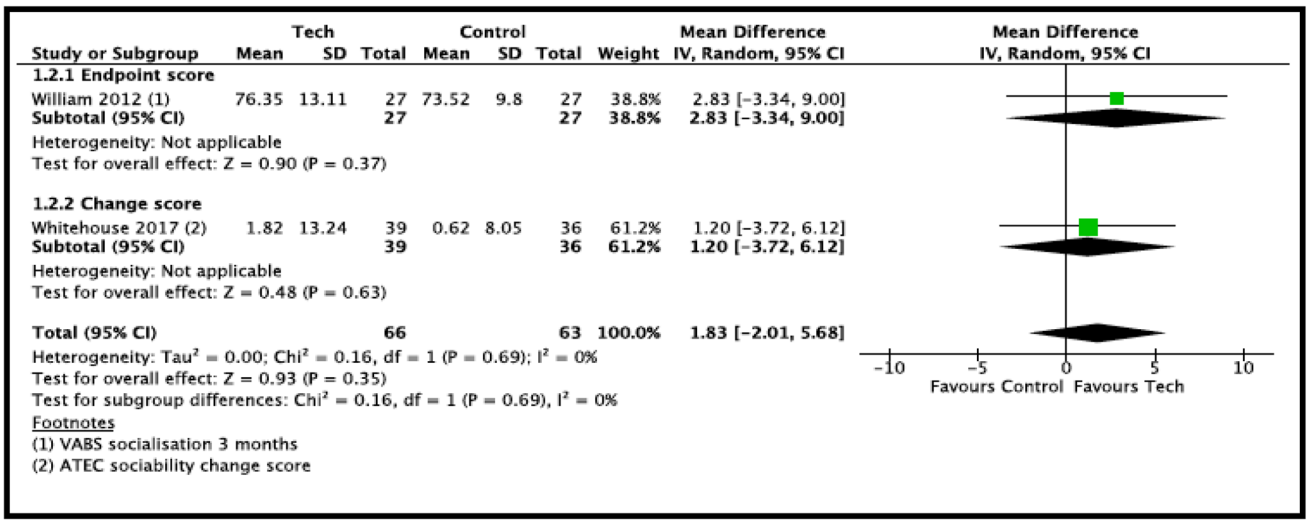
[e]All three trials in this comparison had non blinded assessment and reported positive effects. This could have affected the results. Hence rated as serious risk

[f]Heterogeneity (I2 = 62%) substantial, that cannot be fully explained by differences in population, intervention, comparison or outcome measures hence rated as serious risk

[g]All three studies that measured emotion recognition reported positive effects. Publication bias could not be formally tested because of low number of studies. It is possible that negative results from other trials have not been published. Hence rated as serious risk

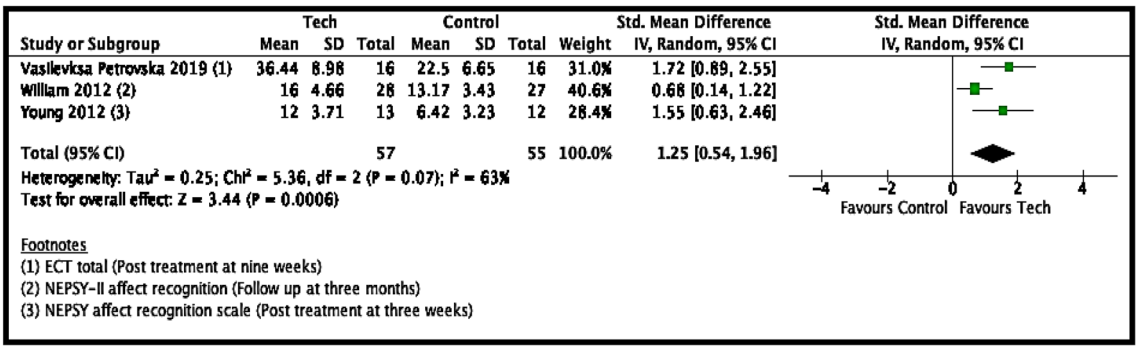
[h]Significant heterogeneity but that can be explained by differences in outcome measurement. Hence rated as not serious risk

[i]The risk in the intervention group (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI)



*size of mean differnce point indicates precision of results

Fig. 3 Forest plot of comparison: 1 Tech assisted Versus Control outcome 1.2 social skills



*size of standard mean difference point indicates precision of results.

Fig. 4 Forest plot of comparison 1 Tech assisted Versus Control outcome 1.3 emotion recognition

trials was d = 0.47 (95% CI 0.008–0.86) (Grynszpan et al., 2014). The results were significant even when they redid the analysis with only the 10 RCTs in their review. Unlike this review where there was separate analysis for each outcome, their meta-analysis averaged the effect sizes of all outcome measures in each study. They included trials with different research designs such as comparing ASD patients with non-ASD patients, pre-post design, ASD patients with and without treatment) delivered in different settings with parent or therapist mediated delivery modes. These differences could explain why they found completely different results to our analyses.

Consistent with results on social communication, analysis of studies that used Vineland adaptive behaviour scale (VABS) social skills measure also revealed negative results for the treatment arm. It is to be noted that previous meta-analysis had not evaluated social functioning (Grynszpan et al., 2014; Moon et al., 2019). Similarly, there were no significant differences between the two arms in any of the language outcomes (language total scores, receptive language, gestures, and expressive language).

The reasons for the lack of effectiveness are unclear. The duration of intervention in app-based studies varied from five min per day for two months (Fletcher-Watson et al., 2016a) to nineteen minutes (average) per day for six months (Whitehouse et al., 2017). It is possible that the apps were used as aids by parents to engage children and did not focus on training parents which may have resulted in greater improvements. It is also likely that the intensity and duration of interventions in these trials were inadequate

to cause clinically meaningful benefits. Two studies with strong quality (Ingersoll et al., 2016; Vismara et al., 2016) involving a 12-week web-based parent training program using multimodality approach reported improvement in parental fidelity. These two small studies indicated a trend towards improving imitation (Vismara et al., 2016) and social functioning (Ingersoll et al., 2016) but did not reach statistical significance. It is worth evaluating if training with greater intensity, duration, and multimodal methods can improve effectiveness. It is worth noting that therapist assisted online training was superior to self-directed learning by parents (Ingersoll et al., 2016). Given that most of the studies included were conducted in developed countries, its generalizability in resource poor developing countries is limited. Studies included also used different classificatory systems and often excluded comorbid disorders which also limits the generalizability of the results.

In contrast, analysis of data on emotion recognition from three trials showed significant improvement in the intervention arms. Compared to the previous analysis in our review on social communication, social functioning and language outcomes in this comparison all three trials had non active controls. Thus, technology-assisted interventions may be better than no intervention in improving social communication outcomes, but this requires further study. However, in those studies that showed improved emotion recognition there was still no clinically meaningful improvement in functional outcomes. There was also a significant risk of bias leading to downgrading the certainty to very low according to GRADE criteria. Other studies have also reported that it is challenging to improve social skills using technology-related interventions (Kelly, 2017).

The quality of studies evaluating technology-based interventions in ASD is improving. In this regard, previous systematic reviews and meta-analyses comprised of studies of variable quality (Ferguson et al., 2019; Grynszpan et al., 2014; Knutsen et al., 2016) which may have impacted the outcomes. However, most of the studies in this review had strong or adequate quality according to criteria established by Reichow et.al (Reichow et al., 2008). Though other systematic reviews in this area had used Cochrane style risk of bias assessments (Griffith et al., 2020; Moon et al., 2019), criteria by Reichow et.al was chosen for this review because of its specificity to interventions for ASD.

Reichow and colleagues have also established criteria for evaluating and determining evidence-based practices in ASD. Two group design studies with strong quality conducted in different geographical locations or four group design studies with adequate quality conducted by two different teams were required to merit consideration as 'established' evidence-based program. Two group design studies of at least adequate quality could qualify for 'promising' evidence-based program (Reichow, 2011). Based on the above criteria none of interventions included in this review fulfilled criteria for either established or promising evidence-based program. Further research is required to understand the predictors for better outcomes while using technology-assisted parent-mediated interventions for ASD.

Limitations

The studies included in this review used different interventions, in different age groups, for varying durations, using diagnostic criteria from different classificatory systems, comparing different control arms and used different outcome measures. Almost all studies were conducted in the developed world impacting on the generalizability of the findings to developing countries. Further, it is possible that several other negative studies were not published and this may have resulted in publication bias. This could not be verified because of small number of studies in each analysis. Search strategy with terms including assistive technology could have resulted in the inclusion of other relevant articles.

Conclusion

There is burgeoning interest in technology-assisted parent-mediated interventions for ASD and quality of trials were mostly adequate or strong. Studies indicate these interventions are feasible, acceptable and users have reported high levels of satisfaction. While studies have shown some promising results in improving emotion recognition, they have not led to significant improvement in other social communication domains or more meaningful functional outcomes. There is currently insufficient data to either support or refute the effectiveness of technology-assisted parent-mediated interventions to improve social communication. At present technology-assisted parent-mediated interventions do not qualify for evidence-based programs for ASD. Greater intensity, duration, parental training, and active therapist involvement may improve outcomes, but these require further examination. There is a need for carefully planned controlled trials with greater consistency of methodology, implementation of standardized assessment tools, longer duration of intervention and protocols for follow-up.

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shortlisting, and selecting articles, extracting information from studies, appraising the quality of studies, comparing with the other authors, contributing and reviewing the draft. KK was involved in the conceptualization, developing protocol, creating search strategy, shortlisting studies, selecting studies, comparing them with other author, extracting information from studies, appraising the quality of studies, meta-analysis, writing up of the draft and reviewing the final draft. SM was involved in conceptualization, selecting studies, extracting data, appraising the quality of studies, writing up of the draft and reviewing the final draft. PK was involved in conceptualisation, finalising the protocol, resolving differences in selection of studies & quality of studies, contribution to the draft and reviewing the final draft. RK was involved in the conceptualisation, extraction of data, meta-analysis, write up and reviewing of the final draft. PR was involved in the conceptualization, analysis, write up and review of the final draft. VE was involved in the analysis, write up and review of the final draft.

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Declarations

Conflict of interest The authors have declared that they have no competing or potential conflict of interest.

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