Digital Interventions for Autism Spectrum Disorder:

A Meta-analysis

Abstract

This study aimed to review digital interventions in the treatment of Autism Spectrum Disorder (ASD). A systematic review and meta-analysis was conducted. Nineteen studies were included. The interventions aimed to improve social skills (n=11), developmental skills (n=2) and 6 other different targets. Technology used were computer programs (n=14), tablet apps (n=3), a robot (n=1) and an interactive DVD (n=1). The meta-analysis resulted in an overall effect size (Cohen’s d) of 0.32 [0.12-0.51], indicating a small effect. Heterogeneity between studies was high (I²=100%), limiting the generalization of results. Therefore, we recommend larger RCT studies, and guidelines for the development of trials evaluating digital interventions for ASD, for making comparison of future studies possible.
Autism spectrum disorder (ASD) is characterized by difficulties in social communication and unusually restricted, repetitive behavior and interests. The most effective interventions are behavioral and educational (Lai, Lombardo, & Baron-Cohen, 2014). However, many families are unable to access interventions due to time consumption and substantial costs (Peters-Scheffer, Didden, Korzilius, & Matson, 2012; Rogge & Janssen, 2019).

An increasing amount of research has investigated the use of digital interventions for support and treatment of autistic individuals under terms such as digital health (Hollis et al., 2017), computer-based (Ramdoss et al., 2011, 2012), computer-assisted (Root, Stevenson, Davis, Geddes-Hall, & Test, 2017), innovative technology-based (Grynszpan, Weiss, Perez-Diaz, & Gal, 2014) and technology-aided interventions (Odom et al., 2015). Devices like computers, smartphones, wearable technologies, virtual reality, robotics and tablets (Odom et al., 2015) have been used. The interventions attempt to teach or train e.g. communication (Ramdoss et al., 2011), social and emotional skills (Ramdoss et al., 2012) and academic skills (Root et al., 2017). The use of digital interventions may be beneficial for autistic individuals, since such interventions are consistent, predictable, and without social interaction, which is preferred by autistic individuals (Golan & Baron-Cohen, 2006). Moreover, digital interventions on commonly used devices such as computers and tablets have the potential to be much cheaper than individual directed live therapy with a clinician (Ramdoss et al., 2012).

A meta-analysis investigating research about digital interventions for ASD was conducted by Grynszpan et al. (2014) including articles published until 2012. Since there has been a rapid growth in the development and evaluation of digital interventions for mental health problems (Hollis et al., 2017) an updated meta-analysis on the subject is of relevance.
The aim of this study was to conduct a systematic review and meta-analysis of digital interventions for Autism Spectrum Disorder, by determining a) the digital devices used, b) the skills targeted, c) the effect size of the interventions and d) quantity and quality of research supporting this.

PICO of the study was:

<table>
<thead>
<tr>
<th>Population</th>
<th>Individuals with Autism Spectrum Disorder in all age groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intervention</td>
<td>Interactive digital interventions</td>
</tr>
<tr>
<td>Comparison</td>
<td>Control group of individuals with Autism Spectrum Disorder, not receiving a targeted digital intervention</td>
</tr>
<tr>
<td>Outcome</td>
<td>Quantitative measure of skill</td>
</tr>
</tbody>
</table>

**Methods**

**Study design**

This is a systematic review and meta-analysis regarding trials of digital interventions in the treatment of Autism Spectrum Disorder. The protocol of the study can be found at [https://www.crd.york.ac.uk/prospero/](https://www.crd.york.ac.uk/prospero/), registration no. CRD42020146542. This systematic review was conducted in accordance with the PRISMA standard (Moher, Liberati, Tetzlaff, & Altman, 2009).

**Search procedure**

A systematic literature search was conducted in the online databases Ovid MEDLINE, Ovid Embase and PsycINFO on the 15th of June 2019. Keywords used for searching were 'Autism', 'digital' and 'trials' and variations of these. MeSH terms, free text, and MeSH trees were used in the search. Full search string can be found at
Furthermore, a hand search was conducted of the reference lists of included studies.

**Study selection and data extraction**

Title/abstract screening followed by full-text screening was performed independently by the first and second authors. Disagreements were resolved through consensus.

Inclusion criteria were a) Studies about interactive digital interventions, defined as interventions with two-way communication between the program and the user, e.g. tablet-based interventions, computer programs, apps for smartphones, wearable devices or virtual reality. b) Participants of any age groups were diagnosed with autism according to DSM-IV (American Psychiatric Association, 2000), DSM-5 (American Psychiatric Association, 2013) or ICD-10 (WHO, 1992). c) Interventions must aim for improvement and measure skills in autistic individuals. d) Controlled trials or randomized controlled trials (RCT) with an intervention group and a control group, both with autism. e) Full-text articles in English published in peer-reviewed journals. Exclusion criteria were a) Interventions based only on conversation with a therapist on a device. b) Studies that assessed improvements in training material without using external outcome measures. c) Studies that relied on single or multiple single-case designs.

Data extraction was conducted including reference and characteristics about study design, participants, interventions and outcomes. During data extraction additional exclusion criteria proved necessary, due to incomparable study designs. Additional exclusion criteria were a) Studies in which the digital intervention was not the main part of the intervention. b) Studies in which the control group received interventions promoting the measured target.
**Quality assessment**

The methodological quality assessment was examined using the Revised Cochrane risk-of-bias tool for randomized trials (RoB 2) (Sterne et al., 2019). Studies were assessed in 5 domains: randomization process, deviations from the intended interventions (effect of assignment to intervention), missing outcome data, measurement of the outcome, and selection of the reported result. Each study was given an overall Rob 2 rating of low risk, some concerns or high risk.

**Data synthesis and statistical analysis**

Stata 16 was used for the statistical analyses. Standardized effect sizes were computed for all studies, due to the diversity between outcome measures. The effect sizes were measured with Cohen’s d (Cohen, 1977). This term is calculated from means and standard deviations from post outcomes of the intervention group and the control group. Magnitudes of Cohen’s d were fixed at 0.2, 0.5, and 0.8, respectively as commonly accepted for small, medium and large (Zakzanis, 2001). Cohen’s d was calculated from the primary outcome. Cohen’s d was calculated for each outcome and averaged if studies had more than one primary outcome. Cohen’s d was calculated from all outcomes measured and averaged if studies did not choose one or more primary outcomes. Results were requested by e-mailing the authors, if effect size could not be found or calculated.

Post outcomes were calculated as a sum of baseline outcomes and change in outcomes, for studies reporting these (Hatfield, Falkmer, Falkmer, & Ciccarelli, 2017; Whitehouse et al., 2017). Standard deviation was assumed to be the standard deviation from baseline measures. Cohen’s d could not be calculated in three studies due to lack of data (Faja, Aylward, Bernier, & Dawson, 2008; Faja et al., 2012; Tanaka et al., 2010). However, these were extracted from the prior meta-analysis (Grynszpan et al., 2014).
Fridenson-Hayo et al. (2017) reported separate outcomes from two identical trials from different countries. Outcomes from the two trials were combined. It was decided that the difference of nationalities would not be of noteworthy impact. Hopkins et al. (2011) reported separate results from participants with the Kaufman Brief Intelligence Test (KBIT) score greater and less than 70 (Kaufman & Kaufman, 1990). This was treated as two individual studies because of the potential of study populations to perform differently. De Vries, Prins, Schmand, & Geurts (2014) examined two different digital interventions with two different targets, why these were also treated as two individual studies.

A random-effects meta-analysis was conducted including all studies, and a random-effects meta-analysis was conducted including only studies with either low risk of bias or with some concerns. Heterogeneity was assessed by computing $I^2$. Thresholds were set as low, moderate, and high to $I^2$ values of 25%, 50%, and 75% (Higgins, Thompson, Deeks, & Altman, 2003).

A random-effects meta-regression of Cohen’s $d$ was performed, testing for association to the duration of the study (in total hours) and age (in age groups, tested overall and between subgroups: <5 years, 5-10 years, >10-15 years (reference), >15 years). Further variables tested were if the intervention target was social skills (including emotion recognition, face recognition and social communication) (yes/no) and if the intervention was assisted by a researcher/health care professional, but not applied to the control group (yes/no). IQ was not considered as a moderator because only one study reported a mean IQ<85. All moderators were tested separately.

Cohen’s $d$ was calculated using only the post-intervention outcome score and standard deviation. Therefore, the potential impact of differences at baseline (scores measured before the intervention period) between the intervention group and the control group was not
considered. To check for significant differences in baseline measures, a two-sample t-test was performed for all baseline measures when available. When not available, test results of baseline measure comparisons were noted if reported.

A noteworthy possible bias of meta-analytical procedures is the tendency for authors, not to publish studies yielding no significant results. To check for publication bias, we conducted a Funnel plot that provided a graphical representation of the relationship between the standard error of included trials and associated effect sizes. A presence of asymmetry was considered potentially indicative of publication bias. Egger’s test was performed as a supplementary test.

**Results**

Figure 1 shows a PRISMA flow diagram of the study selection process.

Twenty-three studies fulfilled the selection criteria. Six publications were discarded due to unavailability of data, despite efforts to contact authors (Humm, Olsen, Be, Fleming, & Smith, 2014; Milne, Raghavendra, Leibbrandt, & Powers, 2018; Mitchell, Parsons, & Leonard, 2007; Silver & Oakes, 2001; Strickland, Coles, & Southern, 2013; Voss et al., 2019). Golan & Baron-Cohen (2006) reported two experiments, where only Experiment 1 fulfilled selection criteria. Two publications each reported two separate interventions (De Vries et al., 2014; Hopkins et al., 2011) adding two more studies to the sample. The resulting 19 studies included 815 participants with ASD.

**Study characteristics**

Overall characteristics of studies are shown in Table 1,

and the characteristics of each study are shown in Table 2.
The overall distribution of digital devices is shown in Figure 2.

The overall distribution of intervention targets is shown in Figure 3.

Assessment of efficacy

The meta-analysis revealed an overall effect size (Cohen’s d) of 0.32 [0.12-0.51], p<0.001, corresponding to a small effect, significantly different from zero. Assessment of heterogeneity revealed an $I^2$ of 100%, corresponding to a very high degree of heterogeneity. A forest plot is shown in Figure 4.

After excluding studies with a high risk of bias, overall effect size (Cohen’s d) was 0.39 [0.16-0.62], p<0.001, $I^2=100\%$, also corresponding to a small effect, significantly different from zero, with a very high heterogeneity.

The meta regression analysis revealed no significant associations between Cohen’s d and any of the variables tested. These were duration of intervention ($\beta=-0.03$, p=0.052), age group, ($\beta=1.93$, p=0.59) age group between subgroups (<5 years: $\beta=-0.35$, p=0.24; 5-10 years: $\beta=0$ (baseline); >10-15 years: $\beta=-0.25$, p=0.36; >15 years: $\beta=-0.27$, p=0.34), assistance by a researcher/health care professional ($\beta=0.41$, p=0.15) or if the intervention target was social skills ($\beta=0.08$, p=0.71).
Baseline differences

Baseline measures are main/primary outcomes before the intervention period, e.g. measures of communication skills. There was no information about baseline measures in two studies (Kumazaki et al., 2017; Tanaka et al., 2010). In Parsons et al. (2019) the baseline was significantly higher for the intervention group compared to the control group in 1 of 6 measures, in Hopkins et al. - *KBIT* > 70 (2011) in 1 of 5 measures and in De Vries et al. - *Working memory training* (2014) in 2 of 4 measures.

In Faja et al. (2012) baseline was significantly higher for the control group compared to the intervention group in 1 of 5 measures and in Lopata et al. (2016) in 1 of 4 measures. There were no significant differences between the intervention group and the control group for all baseline measures in the remaining 12 studies.

Publication bias

Inspection of the funnel plot (Figure 5)

(Page 25)

suggested publication bias, as the study distribution around the pooled mean effect size was asymmetrical. Egger’s test for funnel-plot asymmetry was not statistically significant (p = 0.99), which may be due to the outlying study (Golan et al., 2010) with a large Cohen’s d and very small standard error.

Discussion

This meta-analysis and systematic review included 19 studies, and a total of 815 participants. Trials of digital interventions for autism spectrum disorder were mostly computer-based interventions (n=14) and targets were mainly social skills (n=11). The mean age for trial participants was 10.6 years, and the average duration of the intervention was 12.3 hours. The
A prior meta-analysis on the same subject (Grynszpan et al., 2014) found that interventions were mostly computer-based and targets were mainly social skills and literacy skills. However, all studies in Grynszpan et al. (2014) examining literacy skills included control groups receiving a target promoting intervention. Therefore, the studies focusing on literacy skills were not included in our meta-analysis. A systematic review focusing digital interventions for only adolescents with ASD (Odom et al., 2015) identified additional intervention targets e.g. independence and academic skills, and additional digital devices as smartphones, personal digital assistants and Bluetooth® technology. These studies were either based on single-case designs and/or based on video-modeling, hence they were excluded from the present analysis. One study (Strickland et al., 2013) examining virtual reality intervention was excluded from the present review due to missing outcome data. This suggests that more intervention targets and technologies are being tested than the ones analyzed by our review.

We found the effect size, Cohen’s d for digital interventions to be 0.32 indicating a positive, however small effect. The prior meta-analysis by Grynszpan et al. (2014) found an overall effect size, Cohen’s d of 0.47, indicating a medium effect. However, there are some differences in the selection criteria between this prior and the present meta-analysis. For instance, they included studies with a combination of digital and non-digital interventions and studies comparing two interventions.
This meta-analysis revealed a large heterogeneity, limiting generalization of conclusions. This could be due to the very different intervention targets, procedures, and outcomes of the studies included. Research in this field is in general very different at this point of time, as the field of digital interventions are very young. For instance, there was no tendency for studies to assess the same outcomes, even when promoting the same target. Also, six studies had each different intervention targets. Some studies were excluded because the control condition promoted the intervention target, e.g. a computer program was compared to traditional teaching. Some studies were excluded because the digital interventions were only a smaller part of larger interventions. This suggest that the research field in digital interventions for ASD is still under establishing.

Risk of bias assessment measured with Cochrane’s Risk of Bias tool revealed that only two studies were at low risk of bias, where 13 had some concerns and four had high risk. It remains unclear whether the quality of the studies has an impact on the effect, since there were too few studies with low risk of bias for the conduction of a specific analysis.

Basing our study on the standardized effect size, Cohen’s d, may be a limitation. Cohen’s d is exclusively based on post-intervention outcomes and standard deviation, meaning that potential baseline differences will skew the effect size. To consider this problem, we calculated baseline differences between the intervention group and the control group for all main outcomes available. However, we found no indications for systematic bias in a noteworthy degree on the meta-analytic level; still bias may anyhow occur on a study level.

This meta-analysis suggests that digital interventions for ASD have not proven conclusive efficacy but tends to gain a small effect. It should be considered that these interventions in general are of very short duration (average duration was 12.3 hours overall) compared to traditional therapy. Therefore, long term interventions may increase efficacy. If so, there may
be considerable economic advantages by implementing digital interventions in clinical practice, even if digital interventions show to be of equal efficacy as traditional therapy.

**Conclusion**

The overall effect size of the interventions was positive, however small. Most of the included studies raised some concerns about the risk of bias. There was a pronounced heterogeneity between effect sizes and additionally a risk of publication bias, reducing generalization of results. Therefore, the efficacy is still not proven conclusive. Research in digital interventions for ASD is still too heterogeneous to allow full comparison. Therefore, guidelines for the development of trials are wanted.

We recommend giving priority to larger RCT studies evaluating digital interventions of Autism Spectrum Disorder in future research. Especially, there is a lack of RCT studies evaluating interventions based on smartphones and virtual reality, furthermore on long-term interventions. We suggest designs with the control groups either not receiving an intervention or receiving mock training.
References


Odom, S. L., Thompson, J. L., Hedges, S., Boyd, B. A., Dykstra, J. R., Duda, M. A., … Bord,


Figure Captions

Figure 1. Study selection flow diagram showing the Preferred Reported Items for Systematic reviews and Meta-analyses (PRISMA)

Note: *Two publications each reported two separate interventions, resulting in 19 studies included for analysis.

Figure 2. Overall distribution of digital devices used in interventions.

Figure 3. Overall distribution of intervention targets

Note: Social skills include emotional recognition (n=6), face recognition (n=3) and social communication (n=2). Developmental skills include e.g. visual motor, imitation, language, and social skills. ‘Other’ include anxiety treatment, job interview skills, working memory, cognitive flexibility, attention training and support for transition from high school respectively

Figure 4. Forest plot showing mean effect size (Cohen’s d) and confidence intervals for all studies included

Figure 5. Funnel plot of the meta-analysis
Figure 1 top

**Fig. 1**

*Study selection flow diagram showing the Preferred Reported Items for Systematic reviews and Meta-analyses (PRISMA)*

*Two publications each reported two individual studies, resulting in 19 studies included for analysis.*

Figure made in Word.
Figure 2 top

Fig. 2

*Overall distribution of digital devices used in interventions*

![Bar chart showing digital devices used in interventions]

- Computer program: 14
- Tablet app: 3
- Robot: 1
- Interactive DVD: 1

Figure made in Excel.
Social skills include emotional recognition (n=6), face recognition (n=3) and social communication (n=2). Developmental skills include e.g. visual motor, imitation, language and social skills. ‘Other’ include anxiety treatment, job interview skills, working memory, cognitive flexibility, attention training and support for transition from high school respectively.

Figure made in Excel.
Figure 4 top

Fig. 4

Forest plot showing mean effect size (Cohen’s d) and confidence intervals for all studies included

Figure made in Stata 16.
Figure 5 top

**Fig. 5**

*Funnel plot of the meta-analysis*

Figure made in Stata 16.
Table 1. Study characteristics of included studies about digital interventions for individuals with ASD

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of studies reporting the variable (total=19)</th>
<th>Mean (SD) [range] or %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>n=19</td>
<td>Mean=10.6 (3.4) [3.3-30.7] years</td>
</tr>
<tr>
<td>IQ</td>
<td>n=12</td>
<td>Mean=99.8 (18.1) [54.9-117.2]</td>
</tr>
<tr>
<td>Sample size</td>
<td>n=19</td>
<td>Mean=44.4 (24.1) [10-94] participants</td>
</tr>
<tr>
<td>Gender</td>
<td>n=15</td>
<td>19.5 % females</td>
</tr>
<tr>
<td>Duration</td>
<td>n=18</td>
<td>Mean=12.3 (7.2), [2.5-27.0] hours</td>
</tr>
<tr>
<td>Publication year</td>
<td>n=19</td>
<td>[2006-2019]</td>
</tr>
<tr>
<td>Risk of bias (methodological bias assessed for each study)</td>
<td>n=19</td>
<td>10.5 % (2 studies) Low risk 68.4 % (13 studies) Some concerns 21.1% (4 studies) High risk</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>References (year)</th>
<th>Mean age in years (SD)</th>
<th>Mean IQ (SD)</th>
<th>Met diagnostic criteria (assessment tools)¹</th>
<th>Intervention condition (sample size)</th>
<th>Control condition (sample size)</th>
<th>Training duration</th>
<th>Primary outcomes</th>
<th>Cohen’s d (SD)</th>
<th>Risk of Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conaughton et al. (2017)</td>
<td>9.7 (1.3)</td>
<td>N/A</td>
<td>Childhood Asperger Syndrome Test (CAST)</td>
<td>Anxiety treatment with Cognitive Based Therapy program, called BRAVE ONLINE. Participants receive weekly, online contact with a therapist in response to session activities.¹b (n=21)</td>
<td>Waitlist control. (n=21)</td>
<td>Children: 0.6 h pr. week x 12 weeks  Parents: 0.4 h pr. week x 12 weeks</td>
<td>No. of diagnoses (evaluated using Anxiety Disorders Interview Schedule for DSM-IV)  Clinician Severity Rating (CSR)  The Children's Global Assessment Scale (CGAS)  Child Behavior Checklist - the internalizing scale (CBCL-int)  Spence Children's Anxiety Scale-Child (SCAS-C)  Spence Children's Anxiety Scale-Parent (SCAS-P)</td>
<td>0.88 (1.12)</td>
<td>Some concerns. No protocol found. Missing data not considered in the analysis.</td>
</tr>
<tr>
<td>Faja et al. (2008)</td>
<td>19.7 (5.8)</td>
<td>103.5 (11.9)</td>
<td>Autism Diagnostic Interview Revised (ADI–R), Autism Diagnostic Observation Schedule (ADOS) -module 4, and DSM-IV</td>
<td>Face recognition training with a computer program. (n=5)</td>
<td>No intervention. (n=5)</td>
<td>2.3 h pr. week x 3 weeks</td>
<td>Benton Facial Recognition Test -Long Form  Facial memory task of the Children’s Memory Scale (CMS) or the Wechsler Memory Scale (WMS-III)  Test of sensitivity to second-order relations in faces²  Test of holistic processing of faces²</td>
<td>-0.58 (0.61)</td>
<td>High risk. Not randomized. No protocol found. No information about the blinding of outcome assessors.</td>
</tr>
<tr>
<td>Faja et al. (2012)</td>
<td>22.0 (5.0)</td>
<td>117.3 (16.9)</td>
<td>Autism Diagnostic Interview Revised (ADI–R), Autism Diagnostic Observation Schedule (ADOS) and DSM-IV</td>
<td>Face recognition training with a computer program. (n=9)</td>
<td>Mock training with a computerized training program involving houses. (n=9)</td>
<td>1.5 h x pr. week x 3.2 weeks</td>
<td>Benton Facial Recognition Test -Long Form  Facial memory task of the Wechsler Memory Scale (WMS-III)  Test of sensitivity to second-order relations in faces²  Test of holistic processing of faces²</td>
<td>0.10 (0.31)</td>
<td>Some concerns. No protocol found. No information about blinding of assessors, randomization process and concealing of allocation sequence.</td>
</tr>
<tr>
<td>Fletcher-Watson et al. (2016)</td>
<td>4.1 (1.0)</td>
<td>N/A</td>
<td>Autism Diagnostic Observation Schedule (ADOS) - social communication</td>
<td>Social communication skill training with tablet app FindMe. (n=24)</td>
<td>Waitlist control. (n=25)</td>
<td>0.8 h pr. Week x 10.29 weeks</td>
<td>Brief observation of social communication change (BOSCC)</td>
<td>0.08 (0.02)</td>
<td>Some concerns. The primary outcome in the article is not the same as in the protocol.</td>
</tr>
<tr>
<td>Study and Details</td>
<td>2017: 7.3 (1.1)</td>
<td>2010: 5.9 (1.0)</td>
<td>2006: 30.7 (10.8)</td>
<td>2017: 14.9 (1.2)</td>
<td>2011a: 10.0 (2.6)</td>
<td>2011b: 10.5 (3.3)</td>
<td>Within normal range.</td>
<td>Autism Diagnostic Observation Schedule 2nd ed. (ADOS-2)</td>
<td>Emotion Recognition training with Emotiplay, a Serious Game played on a computer. (n=34)</td>
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<tr>
<td>Fridenson-Hayo et al. (2017)</td>
<td>7.3 (1.1)</td>
<td>5.9 (1.0)</td>
<td>30.7 (10.8)</td>
<td>14.9 (1.2)</td>
<td>10.0 (2.6)</td>
<td>10.5 (3.3)</td>
<td>2 h pr. week x 8 weeks</td>
<td>Emotion recognition training with Emotiplay, a Serious Game played on a computer. (n=34)</td>
<td>Waitlist control. (n=40)</td>
</tr>
<tr>
<td>Golan et al. (2010)</td>
<td>5.9 (1.0)</td>
<td>98.8 (9.4)</td>
<td>111.4 (11.5)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>1.8 h pr. week x 4 weeks</td>
<td>Emotion recognition training with 'The Transporters' interactive DVD. (n=20)</td>
<td>No intervention. (n=18)</td>
</tr>
<tr>
<td>Golan &amp; Baron-Cohen (2006) - Experiment 1</td>
<td>30.7 (10.8)</td>
<td>111.4 (11.5)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>1.8 h pr. week x 10 weeks</td>
<td>Emotion recognition training with Mind Reading computer program. (n=19)</td>
<td>No intervention. (n=22)</td>
</tr>
<tr>
<td>Hatfield et al. (2017)</td>
<td>14.9 (1.2)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Logged in 5 times over one year.</td>
<td>Support of transition from high school with the BOOST-A™, an online program. (n=49)</td>
<td>No intervention. (n=45)</td>
</tr>
<tr>
<td>Hopkins et al. (2011) – KBIT &gt; 70</td>
<td>10.0 (2.6)</td>
<td>92.4 (22.7)</td>
<td>Childhood Autism Rating Scale (CARS)</td>
<td>Emotion and facial recognition training with the FaceSay computer program. (n=13)</td>
<td>Mock-training. (n=11)</td>
<td>0.6 h pr. week x 6 weeks</td>
<td>Emotion recognition in pictures and drawings Benton Facial Recognition Test -Short Form</td>
<td>Benton Facial Recognition Test -Long Form Social Skills rating system (SSRS)</td>
<td>Social Skills Observation (SSO)</td>
</tr>
<tr>
<td>Hopkins et al. (2011) – KBIT &lt; 70</td>
<td>10.5 (3.3)</td>
<td>54.9 (18.8)</td>
<td>Childhood Autism Rating Scale (CARS)</td>
<td>Emotion and facial recognition training with the FaceSay computer program. (n=11)</td>
<td>Mock-training. (14)</td>
<td>0.6 h pr. week x 6 weeks</td>
<td>Emotion recognition in pictures and drawings Benton Facial Recognition Test -Short Form</td>
<td>Benton Facial Recognition Test -Long Form Social Skills rating system (SSRS)</td>
<td>Social Skills Observation (SSO)</td>
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<tr>
<td>Study</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Measure/Intervention</td>
<td>Intervention Details</td>
<td>Randomization</td>
<td>Methodological Concerns</td>
<td></td>
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<tr>
<td>Jouen et al. (2017)</td>
<td>7.0 (1.5)</td>
<td>97.8 (21.5)</td>
<td>Autism Diagnostic Interview Revised (ADI-R)</td>
<td>Training in communication and social interaction with a computer program, GOLIAH</td>
<td>No intervention. (n=10)</td>
<td>Missing data not considered. No protocol found. High risk. Not randomized (allocation based on parent’s motivation)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kumazaki et al. (2019)</td>
<td>21.9 (2.6)</td>
<td>86.7 (12.3)</td>
<td>Diagnostic Interview for Social and Communication Disorders (DISCO)</td>
<td>Job interview training program using an android robot. Teacher assisted through half</td>
<td>Interview guidance by teachers. (n=13)</td>
<td>Some concerns. No information on the handling of missing outcomes. No protocol found.</td>
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<tr>
<td>Lopata, Thomeer, Rodgers, Donnelly, &amp;</td>
<td>8.8 (1.5)</td>
<td>105.7 (13.3)</td>
<td>Autism Diagnostic Interview-Revised (ADI-R)</td>
<td>Emotion Recognition training with Mind Reading computer program as a part of a five-week summer treatment (SummerMAX). (n=18)</td>
<td>Five-week summer treatment (SummerMAX) without the Mind Reading program. (n=18)</td>
<td>Low risk.</td>
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<td>McDonald (2016)</td>
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<tr>
<td>Parsons et al. (2019)</td>
<td>5.2 (1.6)</td>
<td>N/A</td>
<td>N/A</td>
<td>Training in developmental skills with TOBY app on a tablet. (n=30)</td>
<td>Waitlist control. Received tablet, but not the TOBY app. (n=29)</td>
<td>Some concerns. Not blinded outcome assessors. One outcome in the article was not in the protocol.</td>
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<tr>
<td>Spaniol et al. (2018)</td>
<td>8.0 (1.1)</td>
<td>N/A</td>
<td>Diagnostic criteria reviewed</td>
<td>Attention training for strengthening of academic performance with Computerized Progressive Attentional Training (CPAT), a computer program. One-to-one supervision was provided for each child during training. (n=8)</td>
<td>Mock training with standard computer games. One-to-one supervision was provided for each child during mock-training. (n=7)</td>
<td>Some concerns. No information about the randomization process and allocation sequence concealing. Missing data not considered. No protocol found.</td>
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<tr>
<td>Study</td>
<td>Mean (SD)</td>
<td>N/A</td>
<td>Intervention Description</td>
<td>Control Group Description</td>
<td>Hrs/Week</td>
<td>Risk Level</td>
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<tr>
<td>Tanaka et al.</td>
<td>10.9 (3.8)</td>
<td>N/A</td>
<td>Face recognition training with the Let's Face It! Computer games. (n=42)</td>
<td>Waitlist control. (n=37)</td>
<td>1.1 h pr. week x 19.1 weeks.</td>
<td>-0.11 (0.19) High risk. Per-protocol analysis made. No protocol. No information about the randomization process and allocation sequence concealing.</td>
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<tr>
<td>De Vries et al.</td>
<td>10.6 (1.4)</td>
<td>N/A</td>
<td>Flexibility training with Braingame Brian, a computer game. (n=26)</td>
<td>Mock training with Braingame Brian, a computer game. (n=29)</td>
<td>3.1 h pr. week x 6 weeks</td>
<td>-0.18 (0.39) Some concerns. No protocol found.</td>
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<tr>
<td>De Vries et al.</td>
<td>10.5 (1.4)</td>
<td>N/A</td>
<td>Working memory training with Braingame Brian, a computer game. (n=31)</td>
<td>Mock training with Braingame Brian, a computer game. (n=29)</td>
<td>3.1 h pr. week x 6 weeks</td>
<td>0.29 (0.19) Some concerns. No protocol found.</td>
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<td>Whitehouse et al.</td>
<td>3.3 (0.6)</td>
<td>N/A</td>
<td>Developmental skills training with the TOBY app on a tablet. (n=39)</td>
<td>No intervention. (n=36)</td>
<td>1.0 h pr. week x 26 weeks</td>
<td>-0.03 Low risk.</td>
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</tbody>
</table>

N/A: not available; IQ: intelligence quotient; SD: Standard deviation; KBIT: Kaufman Brief Intelligence Test (Kaufman & Kaufman, 1990).

*a All participants had a formal diagnosis of ASD. The screening tools reported was applied at the entry of the trial.

b These interventions were assisted by a researcher/health care professional, not applied to the control group.

c Measurement instruments developed as a part of the study.