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RESEARCH ARTICLE

Facial emotion training as an intervention in autism spectrum disorder: A meta-analysis of randomized controlled trials

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Abstract

A large number of computer-based training programs have been developed as an intervention to help individuals with autism spectrum disorders (ASD) improve their facial emotion recognition ability, as well as social skills. However, it is unclear to what extent these facial emotion training programs can produce beneficial, long-lasting, and generalizable results. Using standard meta-analytic techniques, we investigated the effects of facial emotion training including generalization and maintenance restricted to randomized control trial studies comprising a total of 595 individuals with ASD. Our findings revealed that the intervention resulted in a robust improvement in emotion recognition for individuals receiving training compared with controls. However, while there was also some evidence for generalization of training effects, the small number of studies which conducted follow-ups and assessed social skills reported that improvements were not maintained and there was no evidence for general improvement in social skills. Overall, the analysis revealed a medium effect size in training improvement indicating that facial emotion training may be an effective method for enhancing emotion recognition skills in ASD although more studies are required to assess maintenance of effects and possible general improvements in social skills.

Lay summary

Facial emotion training as an intervention may be a potential way to help improve emotion recognition in autism spectrum disorder (ASD), however robust empirical support for its efficacy has not been sufficiently established. Here, we conducted a meta-analysis of previous studies to summarize the effects of facial emotion training on ASD. Our results show that the training produces a robust improvement in subsequent emotion recognition, while maintenance and generalization effects still need further investigation. To date, no experimentally verified improvements in social skills have been reported.

KEYWORDS
autism spectrum disorder, emotion expression, emotion recognition, emotion understanding, facial emotion training, meta-analysis, social skills

INTRODUCTION

Autism spectrum disorders (ASD) are a group of neurodevelopmental disorders, which are characterized by profound social impairments including failures to respond appropriately to nonverbal cues such as emotional facial expressions (DSM-V: American Psychiatric Association, 2013). The ability to discern emotion from facial expressions and respond appropriately to others is considered essential to adaptive social interaction (Ekman, 1992, 2004) and, as would be expected, individuals with ASD exhibit impairments in facial emotion

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recognition, understanding, and expression (Rump et al., 2009).

The successful encoding and decoding of facial expressions are skills related to higher ratings of social desirability among healthy preschool children (Field & Walden, 1982; Rodgers et al., 2015). However, impairments in emotion expression/regulation (encode) and recognition/understanding (decode) are well documented in ASD children (Rice et al., 2015). For example: (a) Emotion expression: children with ASD often display basic emotions through facial expressions less precisely and less frequently than children without ASD (White et al., 2018), as well as some atypical physiological emotional responding (Dichter et al., 2010). In addition, emotional expression plays a crucial role in establishing and regulating adaptive interpersonal behavior. (b) Emotion regulation: children's sensitivity to emotion cues is a good index of the quality of their social relationships with peers and adults (Pons et al., 2002), as well as labeling of their own emotional states. The ability to accurately label one's emotional state is an important prerequisite for successful emotion regulation (Samson et al., 2012). (c) Emotion recognition: the process of identifying emotion/expressions (Baron-Cohen et al., 1993, 1997). Participants with autism performed significantly worse on tasks where they were required to look at either the face or just a region around the eyes to identify emotions, compared with individuals without autism (Baron-Cohen et al., 1997; Hopkins et al., 2011). Additionally, individuals with ASD may perform worse in recognizing complex emotions due to reduced visual exploration of the eye region (Baron-Cohen et al., 1993; Capps et al., 1992; Lacroix et al., 2014). One possible explanation for this deficit is that individuals with ASD are less good at social referencing, including extracting emotion from presented facial expressions or seeking out emotional information from another's face (Clark et al., 2008; Wolf et al., 2008). (d) Emotion understanding: is firstly the way an individual identifies, predicts, and explains emotion in him/herself and others and secondly shows understanding of the contexts and causes of emotion and how to control it (Grazzani et al., 2018). Indeed, understanding complex emotions such as surprise is linked with theory of mind which is also frequently impaired in ASD (Lacroix et al., 2014). A greater focus on component parts rather than holistic features has often been observed in individuals with pervasive developmental disorders (PDD) (Happé et al., 2001; LoPresti et al., 2008) and might be another explanation for difficulties in ability to understand another's state of mind or emotional state (Hart, 2005; Smitha & Vinod, 2015). Moreover, accurate recognition of others' emotions is also related to theory of mind and empathy (McLellan & McKinlay, 2013).

Emotion reading training has frequently been a target for intervention in ASD. Multiple paradigms, including pictures of faces, eyes, social scenes, and animated objects, in addition to voices of varying intonation and pitch, have been utilized to help individuals with ASD interpret complex emotions and mental states (Reichow & Volkmar, 2010). A large number of computer-based training paradigms have been developed as an intervention which target improvement in facial emotion recognition ability (White et al., 2018). These programs employ an interactive instructional technique where a computer can be used to present the instructional materials and monitor specific abilities such as reading, problem solving and so on. For example, the MiX program was originally designed for typically-developing adults to improve their facial emotion recognition (Russo-Ponsaran et al., 2016); Skillstreaming rooted in both psychology and education focusing on directly introducing principles of learning (McGinnis & Goldstein, 1997). More specifically, computer-based programs have increasingly been used to improve basic and complex emotion recognition in clinical populations which were originally designed for the general population (Rice et al., 2015). Indeed, facial emotion training programs have undoubtedly provided a useful method for receiving instructions and engaging in reciprocal interactions. Emotion trainer (Silver & Oakes, 2001), Face Say (Hopkins et al., 2011), Mindreading (Thomeer et al., 2012), Transporters (Young & Posselt, 2012), and MiX (Russo-Ponsaran et al., 2016) are common computer-based facial emotion training programs used in individuals with ASD. These training programs and others typically work by drawing attention to facial features, such as directing gaze towards the center of the face and the area between the eyes (Combs et al., 2011; Marsh et al., 2012; Russell et al., 2008), which are important for recognizing others' emotions accurately (Combs et al., 2011; Marsh et al., 2012; Wölwer & Frommann, 2011). Additionally, computer and video-based approaches are purposefully designed to create an engaging and motivating environment for training youth with ASD (Esubalew et al., 2012; White et al., 2016). Overall, facial emotion training programs are considered a non-invasive, low-cost approach (White et al., 2018).

A key issue with these types of specific emotion training methods is the extent to which generalization occurs. Generalization is defined as the ability to transfer a skill or behavior acquired in one situation or context to another similar or related one (Koegel et al., 2001). This ability is considered to be limited in individuals with ASD since they may master a skill or routine only in one location or use only one material (Fein et al., 1979). Thus, whether improvements resulting from targeted interventions (facial emotion training) can generalize to other familiar related or different tasks is an important issue in the context of ASD (Golan et al., 2010). Some studies have reported no evidence for generalization of newly acquired skills to related tasks (Silver & Oakes, 2001; Swettenham, 1996). For example, children with autism were taught to understand emotions and this effect was maintained at a 2-month follow-up but the learned skills could not generalize to untaught tasks, such as belief or play tasks (Hadwin et al., 1996, 1997). This absence of generalization may have been due to lack of intrinsic motivation (Dawson & Zanolli, 2003), or using drawings or photographs for training rather than life-like stimuli (Golan & Baron-Cohen, 2006). On the other hand, some studies have reported that improved learning from the training task can be generalized to other stimuli/tasks (Ryan & Charragáin, 2010) or that generalization success is greater for similar (i.e., familiar close) but not distant (i.e., different) tasks, with the training group performing better than the control group in this respect (Golan & Baron- Cohen, 2006). Considering the inconsistent results on generalization across studies, and that ASD subjects have problems with this (Naviaux et al., 2014), an important aspect of our current meta-analysis was to establish the robustness of generalization effects following facial emotion training.

In addition, maintenance of skills learned in the training programs is an important aspect for considering their potential effectiveness as an intervention in ASD. A long period of assessments is required to rigorously evaluate and examine whether beneficial outcomes fade over time (Russo-Ponsaran et al., 2016). In several studies, the magnitude of the intervention effect was lower at follow-up than immediately post-training although significant improvement was still present at follow-up compared with the control group (Gev et al., 2017; Russo-Ponsaran et al., 2016). For example, facial emotion training improved the accuracy and speed of facial expression recognition in children and adolescents with ASD both after the training and at a 4–6 week follow-up, however, the effect size reduced over time (Russo-Ponsaran et al., 2016).

Against this background, we have therefore performed a meta-analysis summarizing the effects of facial emotion training as an intervention in ASD. We employed a strict criterion of only including findings from randomized controlled trials (RCT) to focus on better controlled studies. The aims of the present study were to: (a) provide summary information (age, the type of intervention, maintenance and generalization) on existing research of facial emotion training interventions for children and adolescents with ASD and (b) examine the outcomes (emotion decoding, encoding, and social skills) of these studies and determine whether such interventions may provide positive benefits for ASD.

MATERIALS AND METHODS

Types of studies

All relevant randomized controlled trials (RCTs) were considered for inclusion. RCTs yield average treatment effects that are more reliable than any other empirical methods (Deaton & Cartwright, 2018). Participants must have been assigned to treatment and placebo groups (including no-treatment or standard care control groups).

Types of participants

Individuals who are diagnosed with ASD (i.e., including autistic disorder, Asperger's disorder, and pervasive developmental disorder-not otherwise specified [PDD-NOS] in accordance with DSM-V).

Types of interventions

There is no standard, recommended procedure for facial emotion training as an intervention in ASD. Interventions included in our study, therefore, had the following criteria: (a) they were based on common emotion training theories of autism (e.g., theory of mind); (b) they focused exclusively on any form of facial emotion training (i.e., MiX, Mind Reading) and did not include other training programs (i.e., Virtual Reality Social Cognition Training); (c) they aimed to teach specific skills of emotion recognition, understanding and expression.

Inclusion criteria

All studies included in this meta-analysis met the following inclusion criteria using the PICOS strategy: P (Population): ASD population groups in accordance with DSM-V; I (Intervention): facial emotion training; C (Comparison group): participants received placebo intervention or treatment-as-usual or wait-list control or standard care control; O (Outcome): emotion recognition, emotion expression, emotion understanding, or social skills as outcomes.

Exclusion criteria

Studies were excluded if they failed to satisfy the following exclusion criteria: (a) subjects performed other training interventions which could confound effects of facial emotion training; (b) subjects with reported comorbidities such as Attention Deficit Hyperactivity Disorder (ADHD) or other developmental disorders.

Search strategy

We conducted an electronic database search of PubMed, Elsevier, Web of Science, and Google Scholar. Searches were limited to English language articles published from inception until June 2020 using the following keywords:

facial emotion training, emotion recognition, emotion understanding, emotion expression, emotion regulation, autism, autism spectrum disorder, emotion training, and randomized controlled trials. An additional manual search of references cited within publications identified in the electronic search was also conducted.

Data extraction

Two authors independently screened articles for eligibility. The extracted information was as follows: first author, publication year, country, study design, characteristics of individuals with ASD (sample size, age, gender, diagnosis type, and IQ, training duration), outcomes, and measure methods. A third author was asked to check the final results and required to discuss with the other two authors if she had any questions.

Data analysis

In this study, meta-analysis was performed to assess the effects of facial emotion training using STATA (Statistics and data) software 15.1 and the effect size, standardized mean difference (SMD) as well as 95% confidence intervals (CIs) are presented for each comparison (Takeshima et al., 2014). The effect sizes of standardized mean differences were interpreted as small (SMD ≤ 0.20), medium ($0.20 < \text{SMD} < 0.80$) or large (SMD ≥ 0.80) (Cohen, 2013). The I^2 was utilized to quantify the degree of heterogeneity (Huedo-Medina et al., 2006). There are three typical heterogeneity classifications of I^2: low ($I^2 < 25\%$), moderate ($I^2 \geq 50\%$), and high ($I^2 > 75\%$) (Fournier et al., 2010; Higgins et al., 2019). A random model allows for variations such as different number of participants, the implementations of different interventions, or other reasons, while a fixed effects model assumes there is one true effect and studies were weighted by a function of sample size (Hall & Rosenthal, 2018). Since variations in study characteristics (e.g., sample size, country, age, gender, type of intervention) related to effect size might vary, effects in evaluating emotion recognition and social skills were pooled with a random-effects model, while a fixed-effects model was used to investigate the effect size of emotion understanding/expression due to small sample size (Borenstein et al., 2010). Generalization effects of the training were reported by quantitative description while a fixed-effects model was also conducted to evaluate the effect size of maintenance of the training (Borenstein et al., 2010). Publication bias was examined visually by checking Begg's funnel plots for asymmetry (Song et al., 2002) and statistically by Egger's tests with *p*-value (Harbord et al., 2006). Small sample size limited the power of some tests (sensitivity analysis and publication bias), thus we did not conduct them on emotion understanding or emotion expression.

Review Manager (RevMan, Version 5.0, Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2008) was used to conduct the sensitivity analyses by excluding sequentially each study and re-running the meta-analysis. Sensitivity analyses were used to evaluate whether summary effects and heterogeneity were heavily influenced by a particular case (Higgins et al., 2019; Russo, 2007). Finally, two authors independently assessed quality using the Cochrane risk of bias tool following seven items: random sequence generation; allocation concealing; blinding of participants and personnel; blinding of outcome assessment; incompleteness of outcome data; selective reporting and other sources of bias (Geretsegger et al., 2014; Higgins et al., 2019).

RESULTS

Study characteristics for the included randomized controlled trials

In total, 695 articles were identified through the electronic database search and 37 additional records were identified through other sources. According to inclusion and exclusion criteria, 715 articles were excluded due to duplication of same publications ($n = 131$), not RCT design ($n = 515$), reporting comorbidities ($n = 31$), reviews/meta-analysis ($n = 23$), protocol ($n = 3$), other reasons ($n = 7$), and conference abstracts ($n = 5$). Finally, we included 17 studies (in total $n = 595$ ASD individuals) in our meta-analysis. Table 1 summarizes the basic characteristics for all included studies. These studies were from six different countries: USA, UK, France, Ireland, Macedonia, and Australia, and sample sizes ranged from 10 to 60 with mean ages ranging between 4 and 52 years. While all studies included subjects with ASD in accordance with DSM-V, there was some variability in the participants: eight studies included subjects diagnosed with ASD; eight studies included high functioning autism individuals; one study included low functioning individuals; six studies included individuals with Asperger's disorder and three studies included individuals with PDD-NOS. These studies performed different types of facial emotion interventions including the social skills training group-based program (SST-GP) (Baghdadli et al., 2013), Mind Reading (Golan & Baron-Cohen, 2006), Transporters (Williams et al., 2012), FaceSay (Rice et al., 2015), MiX (Russo-Ponsaran et al., 2016) (see Table 1 and Supplementary materials for details).

Duration of the training/intervention ranged from 1 week to 6 months. Fifteen studies had emotion recognition accuracy as their main outcomes (two of these studies also included emotion expression, six of them also

TABLE 1 Study characteristics for the included randomized controlled trials

Study (author/year)	Country	Sample size	Age (years)	Diagnosis (IQ)	Type of intervention	Duration	Outcomes	Measuring methods	Generalization*
[1]Baghdadli et al., 2013	France	T = 7 C = 7 (M = 14)	8–12	HFA (VIQ:68.50-117.90)	Social skills training group-based program (SST-GP)	6 months	Emotion recognition/ social skills	DANVA2/Kidscreen-27	A positive impact of the training on social skills at school was found although the authors did not report it as a generalization.
[2]Beaumont & Sofronoff, 2008	Australia	T = 26 C = 23 (M = 44)	7–12	AS (IQ:85.00–138.00)	Junior detective training program	7 weeks	Emotion recognition	Assessment of perception of emotion from facial expression	Future studies are needed to quantify.
[3]Golan & Baron-Cohen, 2006	UK	T = 19 C = 22 (M = 31)	17–52	AS/HFA (VIQ:80.00–129.00)	Mind reading	10–15 weeks	Emotion recognition	CAM	Close generalization (new faces and voices) effects but not distinct generalization (complex holistic stimuli) were found.
[4]Golan et al., 2010	UK	T = 20 C = 18	4–7	ASC (VA:76.00–116.00)	The transporters	4 weeks	Emotion recognition	Situation-facial expression matching	Generalization was found in four task levels.
[5]Hopkins et al., 2011	USA	T = 24 C = 25 (M = 44)	6-15	LFA/HFA (VIQ:48.92–100.10)	FaceSay	Over 6 weeks	Emotion recognition/ social skills	Photographs and schematic drawings/ social skills observation	Generalization of emotion recognition skills to schematics of faces and labeling emotions (new). Positive social interactions from parents' reports.
[6]Lopata et al., 2010	USA	T = 18 C = 18 (M = 34)	7–12	HFA/AS/ PDDNOS (IQ:89.00–117.00)	Combine skillstreaming and therapeutic activity	Over 5 weeks	Emotion recognition	DANVA2	Future studies are needed.
[7]Rice et al., 2015	USA	T = 16 C = 15 (M = 28)	5 –11	ASD (FSIQ:86.1–120.72)	FaceSay	10 weeks	Emotion recognition/ social skills	NEPSY-II/Social responsiveness scale-2	Some generalization of social skills from teachers' reports.
[8]Rodgers et al., 2015	USA	T = 30 C = 30 (M = 54)	7–12	HFA (IQ:87.27–118.77)	The summerMAX program	Over 5 weeks	Emotion encoding/ expression	Facial Affect Rating Form	N/R
[9]Russo-Ponsaran et al., 2016	USA	T = 12 C = 13 (M = 20)	8–15	ASD (IQ: 76.49–120.90)	MiX	8 weeks	Emotion recognition/ self-expression	NEPSY-II/emotion self-expression	Generalization in emotion recognition (novel stimuli, assessment formats) was found but not in social functioning (parents' and teachers' reports).
[10]Ryan & Charragáin, 2010	Ireland	T = 20 C = 10 (M = 27)	6–14	ASD (VIQ:73.10-99.85)	Emotion recognition training	4 weeks	Emotion recognition	Emotion vocabulary comprehension test	Generalization of emotion recognition to new materials however future studies are needed in "real life."

(Continues)

TABLE 1 (Continued)

Study (author/year)	Country	Sample size	Age (years)	Diagnosis (IQ)	Type of intervention	Duration	Outcomes	Measuring methods	Generalization*
[11]Silver & Oakes, 2001	UK	T = 11 C = 11	12–18	Autism/AS (minimum verbal IQ requirement)	Emotion trainer	2–3 weeks	Emotion recognition	Emotion cartoon	A very positive result of generalization (predict emotions) to paper based assessment.
[12]Solomon et al., 2004	USA	T = 5 C = 5 (M = 10)	8–12	HFA/AS/PDDNOS (FSIQ:75.00–143.00)	Social adjustment enhancement curriculum	20 weeks	Emotion recognition	DANVA2	Fewer problem behaviors from mothers' reports but future studies are needed.
[13]Thomeer et al., 2012	USA	T = 17 C = 18 (M = 30)	7–12	HFA/AS/PDDNOS (IQ:90.34–117.32)	Combine skillstreaming and Therapeutic activity	Over 5 weeks	Emotion recognition	DANVA2	N/R
[14]Thomeer et al., 2015	USA	T = 22 C = 21 (M = 38)	7–12	HFA (IQ:86.25–116.93)	Mind reading	Over 12 weeks	Emotion recognition/expression/social skills	CAM-C/Social responsiveness scale	N/R
[15]Petrovska & Trajkovski, 2019	Macedonia	T = 16 C = 16 (M = 23)	7–15	Autism (TI/ ID)	Ucime Emocii (learning emotions)	Over 8 weeks	Emotion understanding	Emotion comprehension test (ECT)	Generalization in emotion understanding applied to new faces and scenarios.
[16]Williams et al., 2012	Australia	T = 28 C = 27	4–7	Autism (FSIQ:42.00–107.00)	The transporters	Over 4 weeks	Emotion recognition/social skills	NEPSY-II/Vineland-II socialization domain	Did not generalize in desire-based mind-reading, theory of mind or social skills.
[17]Young & Posselt, 2012	Australia	T = 13 C = 12	4–8	ASD (NVIQ:4.91–15.17)	The transporters	3 weeks	Emotion recognition/social skills	NEPSY-II/Social peer interest	It may help generalization with real human faces used in the training but future studies are needed.

Note: *Golan 2006, Generalization: Four levels tasks included (a) Emotional Vocabulary: participants were asked to define 16 emotion words and give examples of situations. (b) Familiar close generalization: participants had to match familiar situations taken from the intervention series to facial expressions of familiar characters from the series. (c) Unfamiliar close generalization: participants had to match novel situations with novel expressions from the transporters characters. (d) Distant generalization: participants had to match novel situations with novel expressions using a selection of human non-Transporters faces taken from the mind reading software.

Abbreviations: ASD, autism spectrum disorder; AS, Asperger's disorder; ASC, autism spectrum condition; CAM, The Cambridge mindreading face-voice battery; CAM-C, The Cambridge mindreading face-voice battery for children; C, control group; DANVA2, diagnostic analysis of non-verbal accuracy 2; FSIQ, full scale intelligence quotient; HFA, high-functioning autism; IQ, intelligence quotient; ID, intellectual disability; LFA, low-functioning autism; M, male; NEPSY-II, neuropsychological assessment second edition; New, new data set not mentioned in the training sessions; N/R, none report; NVIQ, nonverbal intelligence quotient; PDDNOS, pervasive developmental disorders not otherwise specified; T, training group; TI, typical intelligence quotient; VA, verbal ability; VIQ, verbal intelligence quotient.

included social skills), one study had emotion understanding as its outcome, and one more for emotion expression. Generalization of the training effects was reported in 14 studies, with nine studies showing positive improvements in generalization, four studies suggested further investigation, and one reporting no generalization effect in desire-based mind-reading, theory of mind, or social skills (see Table 1 for details).

Sensitivity analysis

Each study was excluded sequentially to test the stability of the results. For effects of facial emotion training on emotion recognition accuracy, heterogeneity was greatly decreased ($I^2 = 54\%$, $p < 0.0001$) by taking one study out where an error score was provided (Silver & Oakes, 2001) as an accuracy measure in contrast to all the other studies which used a correct score. For effects of facial emotion training on social skills, the sensitivity analysis suggested that heterogeneity did not change significantly ($I^2 = 37\%$, $p = 0.159$) after excluding studies on a one by one case basis (Rice et al., 2015) ($I^2 = 0\%$, $p = 0.415$).

Publication bias assessment

Begg's funnel plot was performed to assess the publication bias. Both symmetry funnel plots indicated an absence of any publication bias (emotion recognition: Egger's test $p = 0.969$; social skills: Egger's test $p = 0.757$, see Figure 1) (Harbord et al., 2006).

Risk of bias

Risk of bias details for each domain are shown in Figures 2 and 3. Only one study (Solomon et al., 2004) was rated as high risk of bias in both reporting and other bias. Three studies were rated as high risk of attrition bias for missing participants (Lopata et al., 2010; Thomeer et al., 2012; Williams et al., 2012). One study was regarded as high risk of other

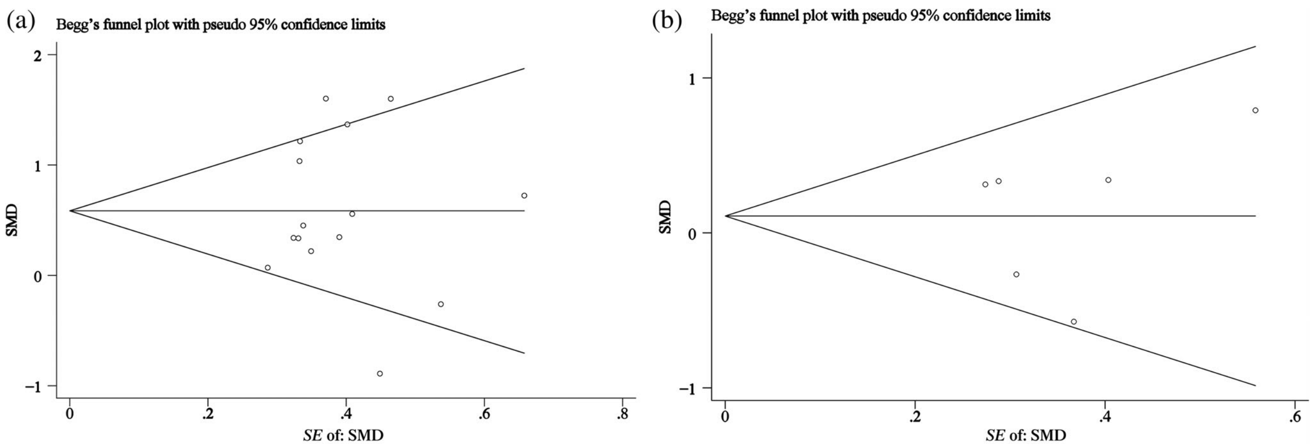

FIGURE 1 Funnel plot of the publication bias across included emotion recognition (a) and social skill (b) studies. SMD, standardized mean difference; *SE*, standard error

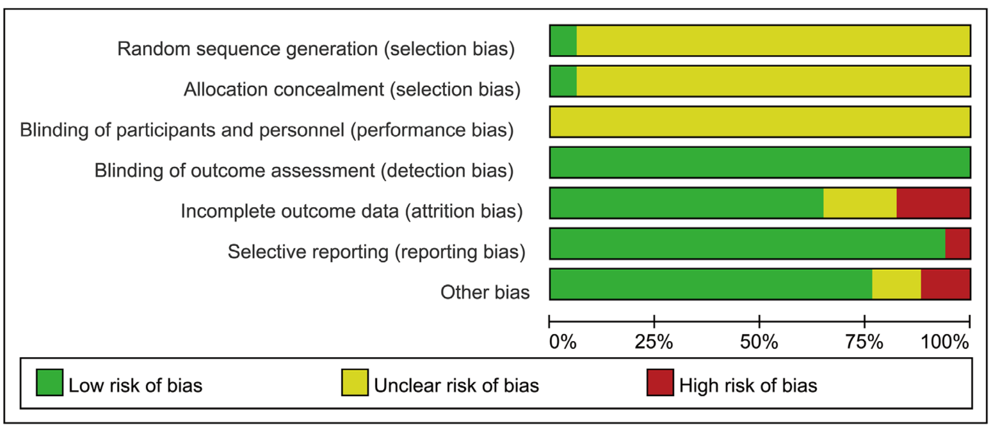

FIGURE 2 Risk of bias graph: Review authors' judgments about each risk of bias item presented as percentages. Green is low risk of bias, yellow is unclear risk of bias, and red is high risk of bias

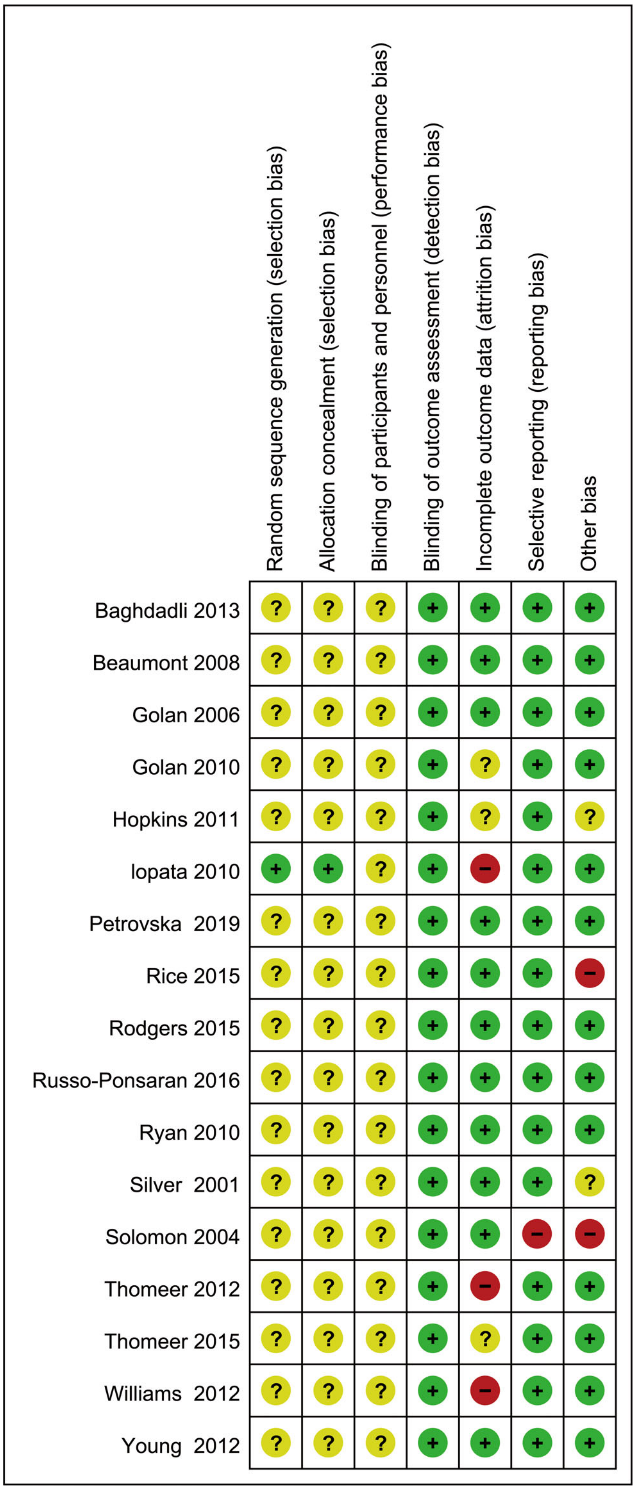

FIGURE 3 Risk of bias summary for each study: Review authors' judgments about each risk of bias item. Green is low risk of bias, yellow is unclear risk of bias, red is high risk of bias

bias due to participants being all high functioning autism, which was not in accordance with the purpose of the experiment aiming to investigate ASD generally (Rice et al., 2015).

The effects of facial emotion training on emotion decoding/encoding and social skills

The effects of facial emotion training on emotion recognition

Fifteen studies were included to investigate the effect of facial emotion training on emotion recognition in ASD. Forest plots showed that between-study heterogeneity was within the accepted range ($I^2 = 65.7\%$). Pooled analysis yielded a medium effect size and indicated that facial emotion training significantly improved emotion recognition accuracy in individuals with ASD (SMD = 0.59, 95% CI [0.26, 0.92], $p < 0.001$, see Figure 4). In addition, results of the effects of facial emotion training on emotion understanding ($N = 1$, see Table 1 [15], sample size = 32, training group =16) and expression ($N = 3$, see Table 1 [8, 9, 14], sample size = 128, training group = 64) in ASD are provided in the supplementary material (Figures S1–S2).

The effects of facial emotion training on social skills

We examined the effects of facial emotion training on social skills in six studies (see Table 1 [1, 5, 7, 14, 16, 17]) and the results indicated that the training did not influence social skills in individuals with ASD (SMD = 0.11, 95% CI [−0.24, 0.46], $p = 0.537$, $I^2 = 37.0\%$, see Figure 5).

Maintenance of facial emotion training effects

Four studies (2, 9, 14, 16, see Table 1) were included to examine the maintenance of facial emotion training effects. Forest plot results show a moderate heterogeneity ($I^2 = 67.9\%$) in the maintenance of facial emotion training compared with immediate post-training effects in ASD. Pooled analyses suggested that the ability of emotion recognition was not maintained after facial emotion training in individuals with ASD (SMD = 0.28, 95%CI (−0.59, 0.04), $p = 0.083$, see Figure 6).

DISCUSSION

In the current meta-analysis study, we investigated the effects of facial emotion training in studies including a total of 595 participants with ASD and found that the intervention resulted in robust improvement in emotion recognition for individuals receiving training compared with controls. Overall, the analysis revealed a medium effect size in post-training training improvement indicating that facial emotion training may be an effective method for enhancing emotion recognition skills in ASD.

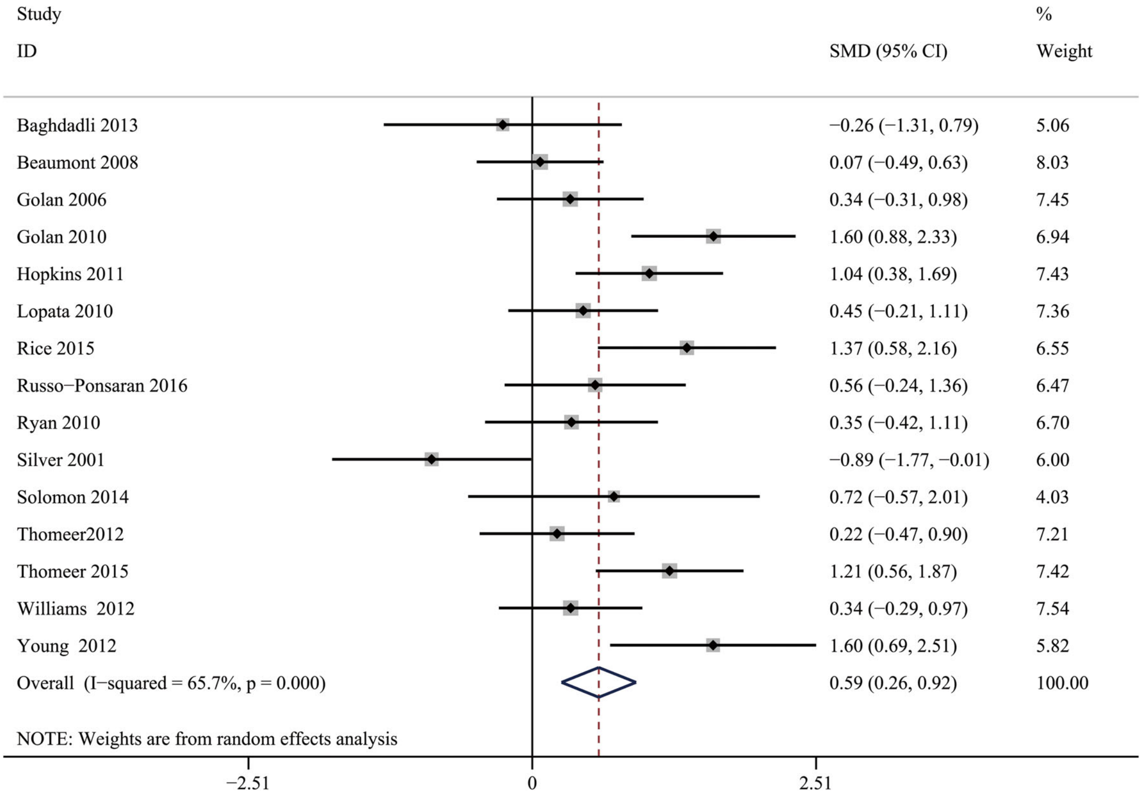

FIGURE 4 Forest plot showing the effects of facial emotion training on emotion recognition in ASD. The plot gives study information, standardized mean difference (SMD), 95% confidence interval (CI) and % weight. Solid vertical line represents the line of no effect (i.e., cut-off), the dotted vertical line is the combined SMD

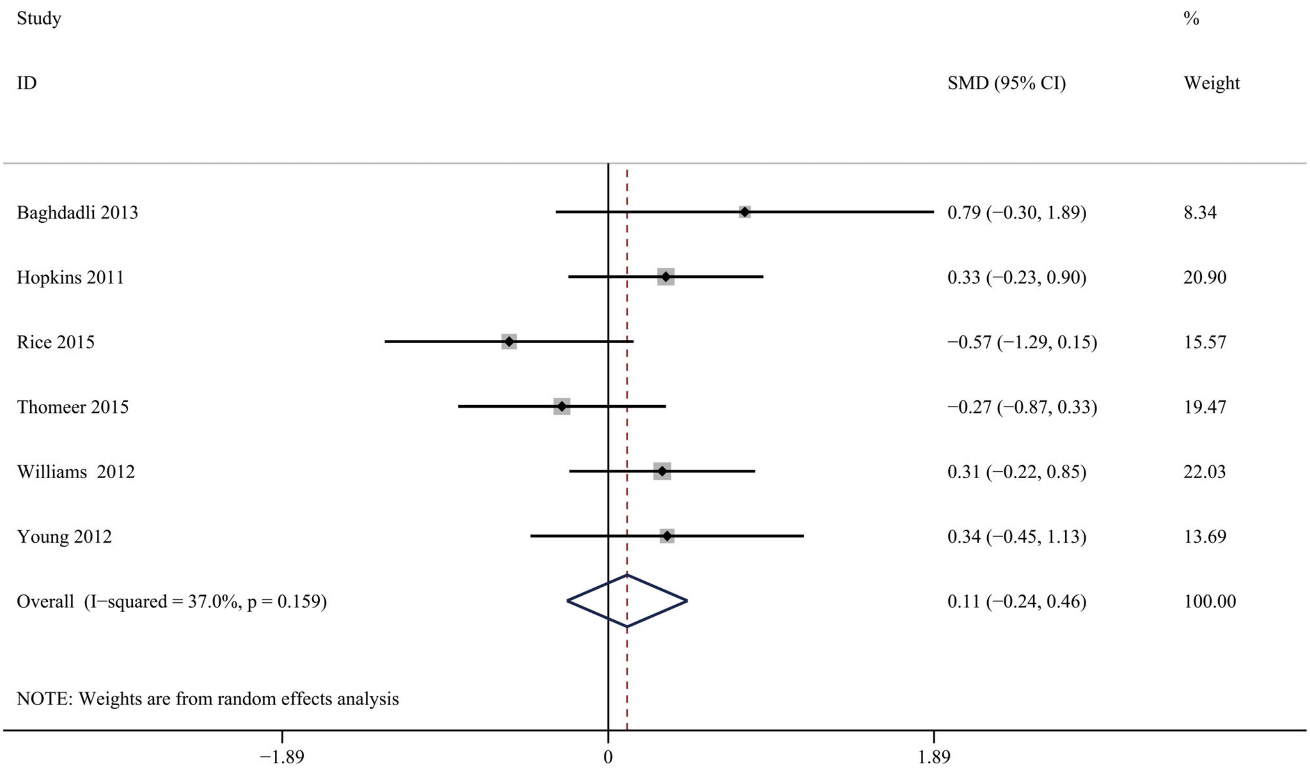

FIGURE 5 Forest plot showing the effects of facial emotion training on social skills in ASD. The plot gives study information, standardized mean difference (SMD), 95% confidence interval (CI), and % weight. Solid vertical line represents the line of no effect (i.e., cut-off), the dotted vertical line is the combined SMD

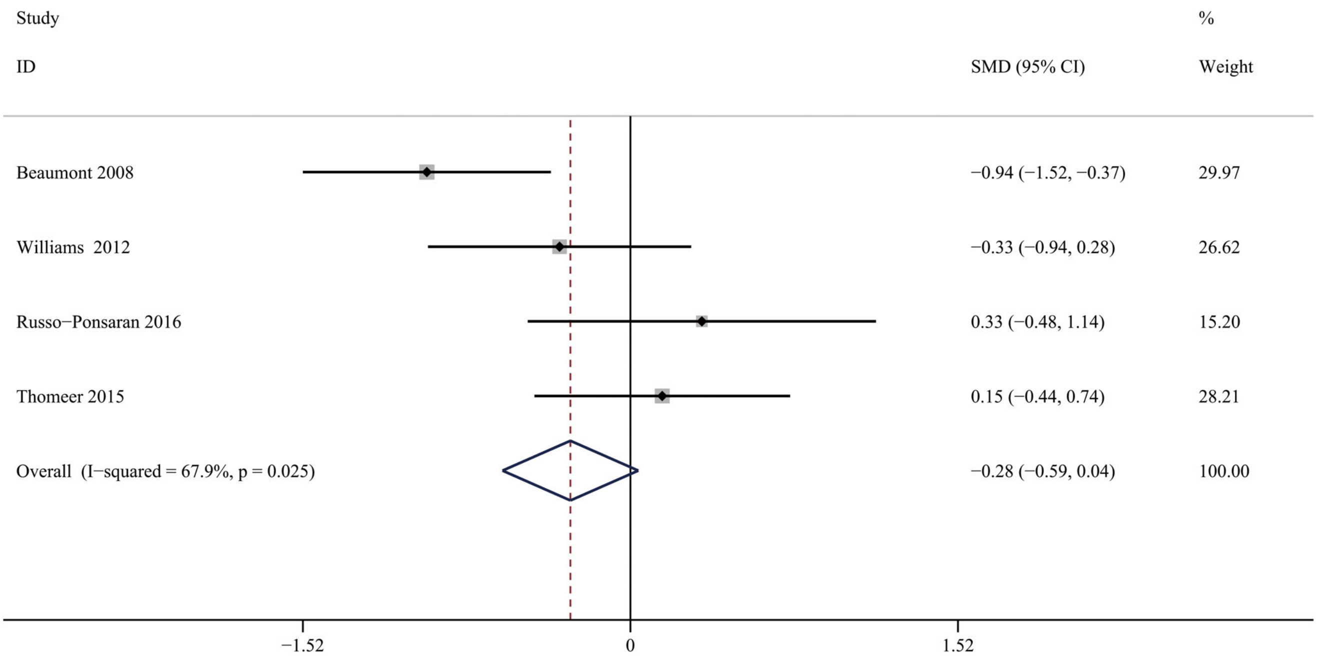

FIGURE 6 Forest plot showing maintenance of facial emotion training effects in ASD. The plot gives study information, standardized mean difference (SMD), 95% confidence interval (CI), and % weight. Solid vertical line represents the line of no effect (i.e., cut-off), the dotted vertical line is the combined SMD

However, there was no evidence for training improvement in social skills, although relatively few studies have investigated this to date. In addition, there was also evidence for some generalization of training effects both in terms of similar (i.e., from old faces to new faces) and also different (i.e., from Transporters' faces to human faces) contexts, although future studies are still needed to fully establish the robustness of such generalization effects.

Computer-based training can provide realistic and structured environments and multisensory/reciprocal interactions, which help to motivate participants (Hopkins et al., 2011; Moore et al., 2000; Smith & Sung, 2014). Additionally, they provide a repetitive and consistent approach which both children and parents can use at their own pace, creating intrinsic motivation, and subsequent progress (Bernard-Opitz et al., 1990; Chen & Bernard-Opitz, 1993; Golan et al., 2007; Rice et al., 2015). Thus, these computer-based training programs might play a useful role in helping ASD children to improve their face emotion recognition skills.

It is possible that individuals with ASD acquired improved ability for recognizing face emotions following training due to learning to rely more on global rather than local features. Previous studies have suggested that individuals with ASD tend to use local more than global features for recognizing faces, particularly the area around the eyes (Behrmann et al., 2006; Harms et al., 2010). For example, the lower part of the face, such as the mouth, tends to evoke positive emotions, whereas the upper part, such as the eyes tends to evoke negative emotions (Bal et al., 2010; Dimberg & Petterson, 2000; Smitha & Vinod, 2015). When information from specific face features such as the eyes is withheld, individuals with ASD find it more difficult to infer others' mental states (Pelphrey et al., 2007), suggesting that the processes of face recognition and emotion recognition are overlapping.

It should be emphasized however that it is still unclear how ASD influences the respective dependence of local and global processing of emotion cues (Simmons & Todorova, 2018) and none of the training studies in the current meta-analysis investigated this aspect as a training outcome. An important additional component which would help to identify the effects of the training on the way ASD individuals actually process faces would be to include eye-tracking assessments, but again unfortunately, to date, no emotion recognition training study has incorporated eye-tracking methodology.

On the other hand, the observation that facial emotion training can improve emotion recognition abilities in individuals with ASD may support exposure theory described in previous studies (Gauthier et al., 2000). Typically developing children acquire facial recognition skills through attending to the large number of faces they are exposed to during early development, while children with ASD tend to avoid looking at faces during this key period and this may inhibit the acquisition of face recognition skills. All the studies included in the current meta-analysis provided participants with increased exposure to both static and dynamic faces with different basic facial expressions such as happiness, sadness, anger, and fear during training (Rice et al., 2015). Therefore, increased exposure to faces during training may be another reason for observed improvement.

By contrast, we found the facial emotion training did not influence social skills in ASD compared with control groups. Social skills are generally regarded as a group of comprehensive abilities such as integrating social cues, processing social information, and engaging in social modeling (Koegel et al., 1995; Modugumudi et al., 2013). A more comprehensive intervention may therefore be required for individuals with ASD due to their variable specific needs (Ke et al., 2018). In addition, some previous studies have suggested that long-term (>10 weeks) compared with short-term (<10 weeks) training sessions were more effective (Laugeson et al., 2012; Lerner & Mikami, 2012; Tse et al., 2007). The length of the training sessions could therefore be another reason for the limited evidence of effectiveness on social skills. More studies are needed in the future to confirm the effects of facial emotion training on social skills.

There was no evidence for post-training maintenance of skills in follow-up assessments made in four of the studies. This may due to parents/caregivers not being involved in the experimental training and therefore not reinforcing it in the home environment. In three of the studies including a follow-up (Beaumont & Sofronoff, 2008; Russo-Ponsaran et al., 2016; Thomeer et al., 2015) participants were trained alone by the trainers in an experimental room and in a fourth study they were asked to watch a DVD by themselves (Williams et al., 2012). One other study reported that during the intervention, parents also learned strategies for teaching and promoting generalization of skills, and the protocol was perceived by parents as positively affecting their children's facial expressions of emotions (Thomeer et al., 2015). When parents are permitted to organize and provide more learning opportunities for children in a range of situations, this is also advantageous for maintenance of learning and facilitates mutual support at the same time (Baxendale et al., 2001; McConachie & Diggle, 2007; Symon, 2001). Parents/caregiver-delivered interventions could increase caregiver involvement and one meta-analysis suggested the strategy resulted in improved maintenance of effects (Hong et al., 2018). Therefore, parents or caregiver-implemented interventions should be taken into consideration when applying training programs.

Our results also showed a positive generalization effect of emotion recognition training in that the learned skills in the intervention group could transfer into other contexts or situations. Some of the programs added settings to enhance generalization (Golan & Baron-Cohen, 2006) such as self-monitoring techniques (Rice et al., 2015). Making materials presented in the programs natural and life-like (Golan et al., 2010) may make the intervention easier to translate learned skills in a laboratory setting into everyday social interaction and communication (Rice et al., 2015). For example, real-life faces of actors were used to show emotions and contextualized in positive social interactions between toy vehicles in a children's animation series called "The Transporters" (www.thetransporters.com) (Golan et al., 2010). The success of generalization indicated that the interventions could alter behaviors such as social skills, and these learned behaviors could be transferred into automatic or internal reactions. In addition, two of included studies recruited adults (age ≥ 18 years) and age should be taken into consideration in future studies. Development of a neural system specialized for face processing may rely on the exposure to faces during a key sensitive period. In the future, more studies are needed to establish the importance of age in success of intervention training, to investigate maintenance as well as immediate training effects and generalization in both similar and different contexts (Calderoni et al., 2016; Dawson & Zanolli, 2003).

The results of the present study should be interpreted with caution, given some limitations. Firstly, only moderate heterogeneity ($I^2 = 65.7\%$) was found for the data presented in the included studies. I^2 describes the percentage of variability due to heterogeneity rather than sampling error, and is a favored measure for quantifying heterogeneity (Higgins & Thompson, 2002; Ioannidis, 2008). Generally, forest plots combined with I^2 are performed to estimate between-study heterogeneity. Although I^2 does not depend on the number of studies (Patsopoulos et al., 2008), it is influenced by the sample sizes of individual studies (Coory, 2010; Higgins & Thompson, 2002). Due to unequal sample sizes in the included randomized controlled trials, while we had an acceptable heterogeneity it was not ideal (Coory, 2010). Secondly, the included studies for emotion understanding ($N = 1$) and expression ($N = 3$) were limited and therefore we could not carry out some data analyses, including sensitivity analysis and publication bias. Thus, this question should be addressed in future studies.

In summary, our meta-analysis for RCTs of facial emotion training in ASD supported its efficacy in improving accuracy in face emotion recognition with a medium effect size. Studies also indicated that the training effects generalized to other contexts but that they were not maintained at follow-up and did not improve general social skills. There is a need to raise awareness of the strengths of these training interventions for both clinicians and parents. However, future studies would benefit from larger and more diverse samples, incorporating aspects such as more involvement of parents and caregivers in the training, follow-up assessments (generalization/maintenance), and use of methodologies to help determine more precisely the impact of training on the way ASD individuals process face emotions. Informed consent was provided by caregivers or participants in all studies. For ethical approval information please see individual studies.

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AUTHOR CONTRIBUTIONS

Qianqian Zhang and Keith M. Kendrick conceived and designed the study; Qianqian Zhang, Renjing Wu, and Siyu Zhu conducted the analysis; Renjing Wu, Jiao Le, Chunmei Lan, Yuanshu Chen extracted the study information, Qianqian Zhang, Weihua Zhao, Keith M. Kendrick, and Qianqian Zhang drafted the manuscript. Shuxia Yao, Weihua Zhao, and Keith M. Kendrick interpreted the results and revised it critically for important intellectual content and finalized the manuscript for submission. All authors reviewed the final manuscript. Informed consent was provided by caregivers or participants in all studies. For ethical approval information please see individual studies.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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